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Aspects of the Biology of the Tortugas Pink Shrimp, *Penaeus duorarum*[1]

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ABSTRACT

On the Tortugas grounds, off southern Florida, the female pink shrimp *(Penaeus duorarum)* had an estimated winter growth of 5 counts per pound per month (number of shrimp per pound with heads off). The males grew 7 counts per pound per month. The shrimp were tagged with Petersen disc tags. A general tendency was noted for the adult shrimp to move in a northwesterly direction. Female shrimp attain larger size than males in the Tortugas grounds and growth of the carapace, which is more easily measured than total length, is related linearly to total length. Size-frequency distributions suggest that small shrimp move from shallow water at the end of the Florida peninsula to the Tortugas grounds. Some salinity and temperature data are given.

INTRODUCTION

The pink shrimp *(Penaeus duorarum)* provides an important commercial fishery off both Florida coasts. About 29 million pounds were taken in 1956 (Idyll, 1957). The principal fishing grounds, however, is an area of about 1,500 square miles immediately west of the tip of Florida between Key West and Dry Tortugas. Larger shrimp are taken for processing as human food, but there is also a considerable fishery for smaller shrimp which are used as bait for many sport fish (Higman, 1952). Shrimp fishing on the Tortugas is by otter trawls and the principal ports at which the catch is landed are Key West, Marathon, Everglades, Naples, and Ft. Myers.

Management of this shrimp fishery requires a complete understanding of the life history of the shrimp, including knowledge of its early life and feeding habits, growth and mortality, spawning behavior, migration, and information on the fish predators that feed on it. At present such information is scanty and a fishing regulation now in force, intended to sustain and increase production, is based on insufficient scientific evidence to insure that it will be effective.

During a study of the Florida Bay (Figure 1) bait fishery (Higman, 1952) information was gathered on sizes of shrimp in the Bay and those passing out into the Atlantic through the channels between the keys. These unpublished data indicate movement out of the Bay area and possible value of this area as a nursery ground for Tortugas shrimp. The present paper reports some phases of the biological research on shrimp sponsored by the Florida State Board of Conservation, principally during the period July 1957 to June 1958. Since the shrimp investigation is in its initial stage, the conclusions presented must be regarded as tentative.

DISTRIBUTION OF FLORIDA PINK SHRIMP

Pink shrimp are distributed along the east and west coasts of Florida. The Tortugas grounds are bounded on the south and west by deep water which appears to be a natural barrier to their movement in those directions. To the east the shallow waters of Florida Bay contain small shrimp, and from this area the majority of pink shrimp are believed to emigrate to the Tortugas grounds (Figure 1). To the north is an area which is largely untrawlable, probably providing protection to a portion of the population of pink shrimp.

[1]Contribution No. 246, The Marine Laboratory, University of Miami

Pink shrimp are caught to the north of Tortugas at various locations. Catches are occasionally made in the open sea off Sanibel Island near Ft. Myers Beach (Figure 1). These catches are usually made only in the spring of the year and are small in comparison to the Tortugas landings. In 1957, for example, U. S. Fish and Wildlife Service unpublished records show that about 269,000 pounds were landed from fishing in the Sanibel area and about 9,700,000 pounds were caught in the Tortugas area proper. Occasionally commercial quantities of pink shrimp are caught off Tampa Bay. These catches are generally from small fishing areas that produce commercial quantities for only short periods but are attractive to fishermen who sometimes make very high catches with relatively little effort.

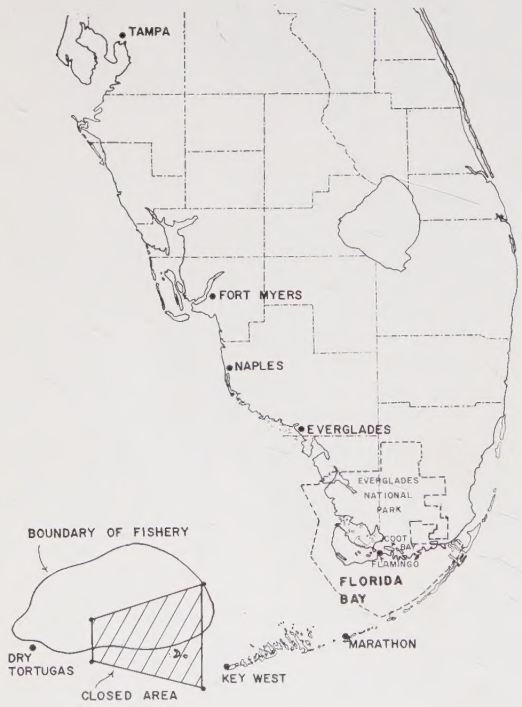

FIGURE 1. — Chart showing the Tortugas fishing grounds, the principal fishing ports, and the area where fishing is sometimes restricted by the Florida State Board of Conservation.

On the west coast of Florida from Naples to Cedar Key, there is a bait shrimp fishery for pink shrimp in which about 96 boats were engaged in 1955 (Woodburn *et al.*, 1957). Because large numbers of pink shrimp are found to the north of Tortugas, the question of the relationship of these stocks to the stocks on the Tortugas is raised.

ECOLOGY

During the study of "trash fish" caught by shrimp trawlers, Siebenaler (1952) identified 32 species of fish and 20 species of invertebrates from the Tortugas grounds. Based on his findings and later collections it appears that pink shrimp are an important food for many other marine animals, and efforts are being made to identify the principal predators. There are other species of shrimp on the Tortugas grounds besides the pink shrimp, but the pink shrimp is the only species that is at all common in the catches.

A full physical description of the Tortugas grounds is lacking, but observations have been made by Mr. James Regan on temperature and surface salinity. In addition, bathythermograms were made from 1955 to 1956. These hydrographic observations were made incidental to the study of the effect of mesh sizes on shrimp escapement, but were not all well distributed over the grounds and were not made all months of the year (no observations were made in May and October). Because of these limitations they are principally of value in the planning of a future detailed hydrographic survey. Surface salinity values and temperatures for the 10 months were quite consistent, with an average value for surface temperature of 77.8°F. and a range from 71.0° to 86.7°F. Examination of bathythermograms shows a thermocline forms at times during the summer but that temperature discontinuities generally break down during periods of high winds (usually winter). The surface temperatures in the winter in the low 70's likely indicate similar bottom temperatures, but higher summer temperatures from 81.2°F. to 86.4°F. do not necessarily indicate similar bottom temperatures. Bottom salinity values for samples taken at 10 to 15 fathoms during the year ranged from 36.15 to 37.73 parts per thousand.

EARLY LIFE HISTORY

Detailed knowledge of the larval life history of *P. duorarum* is lacking, but this phase of the life history is now being studied.

Information is accumulating on the occurrence of small adults. In a 1951 and 1952 study of the Florida Keys and Florida Bay bait fisheries an accurate evaluation of the

abundance of shrimp throughout the year was not possible because no records were kept by fishermen. Earnings of bait fishermen, however, provided an indirect indication of abundance. Figures, kindly provided for all months of the year by both bridge-net fishermen and bait-boat (frame trawlers) fishermen, suggest higher catches during the winter months than in the summer months. The fishermen stated that catches made during the winter required less effort than during the summer. This reported winter peak of abundance of small shrimp in the Florida Bay and Keys area coincides with that indicated by dealers' records for the Tortugas fishing grounds.

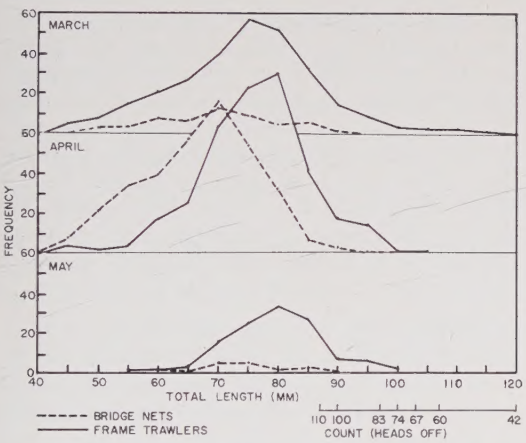

FIGURE 2.—Length-frequency distributions of pink shrimp caught in Florida Bay, March to May, 1951.

Observations of the size distribution of the shrimp in the bait fishery were made for nearly all months of the year from both bridge-net and bait-boat catches. The size distributions shown in Figure 2 for March-May 1951 are typical of sizes in other months, the modes in these distributions generally being around 7 to 8 centimeters, total length. Such shrimp weigh less than 110 per pound with the heads off (110 "count"). It is significant that throughout the year few large shrimp (larger than 83 count) were taken. This is one of the several pieces of evidence suggesting that Florida Bay estuaries serve as nursery grounds for the small shrimp, and that as the shrimp grow they move to deeper water.

SIZES OF PINK SHRIMP

In the early shrimp investigations in Florida Bay measurements were made with calipers from the tip of the rostrum to the end of the telson and recorded as total length. Subsequently only the carapace length measurements were made, measuring from the orbital notch to the hind margin of the cephalothorax. The carapace measurement is superior because it eliminates incorrect observations resulting from mechanical stretching of the abdominal segments and errors caused by the curvature of the abdomen. Average relationships between carapace length, total length, and count per pound, heads off, for shrimp of both sexes combined are shown in Table 1 and the approximately linear relationship between the carapace length and total length for both males and females is presented in Figure 3.

TABLE 1.—*Length-weight relationship of pink shrimp, male and female shrimp combined*[1]

Carapace length (millimeters) (orbital groove to hind margin of carapace)	Total length (millimeters) (includes rostrum)	Count, heads off (i.e. number of headless shrimp per pound)
20	87	110
21	90	100
22	93	92
23	97	83
24	100	74
25	103	67
26	107	60
27	110	55
28	113	51
29	117	46
30	120	42
31	123	39
32	127	36
33	130	33
34	133	31
35	137	28
36	140	26
37	143	25
38	147	23
39	150	21
40	153	20
41	156	19
42	160	18
43	163	17
44	166	16
45	170	15
46	173	14
47	176	13
48	180	13
49	183	12
50	186	11

[1]Based on samples collected during March and September, 1956.

On the fishing grounds female pink shrimp attain a larger size than males and the modes of size distributions of each sex in the catch may differ considerably. This difference in modal size is illustrated by the distribution from samples taken during August 1956 on a research vessel on the Tortugas grounds (Figure 4) but is typical for samples taken throughout the year.

Our observations concur with those of Williams (1955) who, when describing sizes of pink shrimp from North Carolina, states: "There is a sex size disparity in adult *P. duorarum* which is statistically significant at mean total lengths which exceed 100 millimeters."

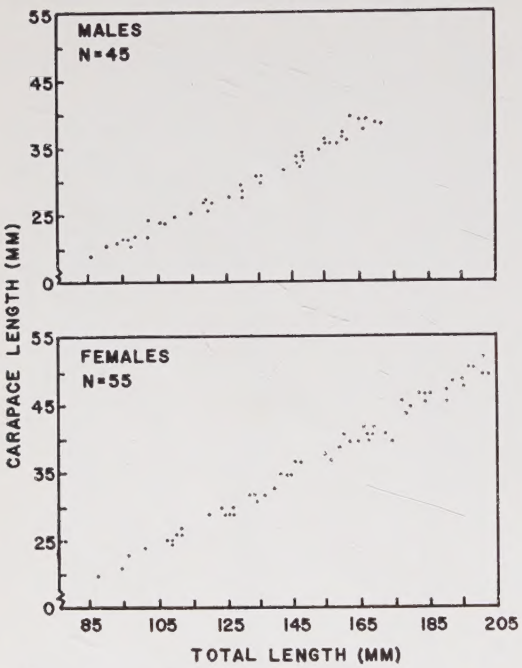

FIGURE 3.—Relationship of pink shrimp carapace length to total length, September 23, 1957 to September 25, 1957.

SEX RATIO

Since there is a size difference between the sexes and since the size of shrimp caught is influenced by mesh size used, the ratio of sexes occurring in the catches is altered by using different sized meshes. Interpretation of sex ratios must thus be examined with this factor in mind.

The sex-ratio data gathered so far do not suggest a pattern, but it is possible that larger samples from individual areas and depths taken throughout the year will provide data that will have some bearing on the biology of the pink shrimp. Our preliminary data show wide variation around a 1:1 ratio.

TAGGING EXPERIMENTS

To obtain information on growth and movement tagged shrimp have been released on the fishing grounds, and considerable numbers of smaller shrimp have been tagged in an estuary on the southern end of the Florida peninsula.

Shrimp were tagged with Petersen discs using the method described by Lindner and Anderson (1956) for white shrimp *(P. setiferus)*. Tags used on pink shrimp measure 5/16 inch in diameter and are 0.020 inch thick. Limited observations on tagged shrimp kept in tanks encouraged the use of Petersen tags for studies of movement and growth of pink shrimp.

Shrimp were tagged on the fishing grounds from catches of commercial boats. In almost all cases the shrimp were obtained from try nets (small otter trawls of about 15- to 20-foot spread, used to "try" an area for shrimp) generally from short hauls of 15 to 20 minutes, since these shrimp are relatively undamaged. As soon as the shrimp were brought on board they were placed in a large plastic bucket filled with fresh sea water. From here the shrimp were tagged, measured, and sexed as quickly as possible and placed in another large plastic bucket. When all shrimp from a particular haul had been tagged, they were released over the side of the vessel en masse. It is expected that there was less loss from predation by this release method than if the shrimp had been released one at a time.

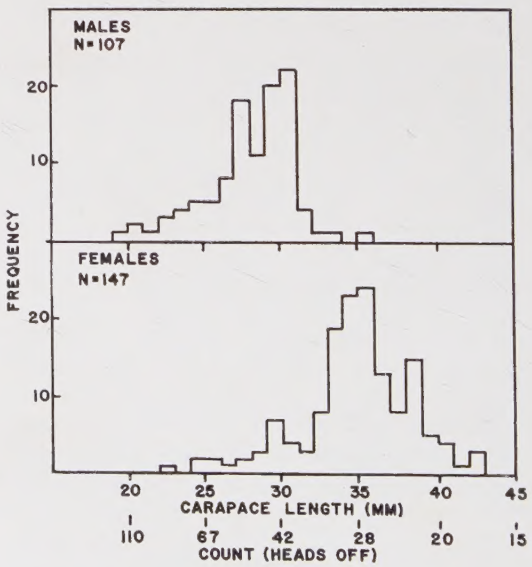

FIGURE 4.—Length-frequency distributions of pink shrimp taken by 2¼-inch cod end with 1-inch cover bag, August 16-17, 1956.

Occasionally when try-net catches did not supply enough shrimp for tagging, some of the shrimp in better condition were tagged that had been taken in hauls of about an hour by the large net. Using shrimp from the large nets, however, apparently reduced the recovery rate because of 914 shrimp tagged from the try nets 205 were recovered (about 22 percent) and of 368 tagged from the main net, 53 were recovered (about 14 percent). For these data $\chi^2=10.51$, d.f.$=1$, probability <0.01. Since these results were gotten over the same general period (December 1957—June 1958) and the same areas on the grounds, they suggest that the try-net shrimp have a better chance to survive the tagging operation.

To publicize the program information was given to newspapers in the shrimp ports shown in Figure 1, and all shrimp dealers were provided with posters describing the program, along with books to record recovery information, and bottles with formalin to hold tagged shrimp. Because boats from Cuba also fish the grounds, they were encouraged to turn in any tagged shrimp they might catch. Dealers are visited at intervals and all tagged shrimp on hand are picked up.

A reward of 50 cents per tag was offered, the fishermen being asked to return the whole animal, along with information on place and time of capture.

The summary of tagging experiments by dates and areas is shown in Table 2, which covers from December 1957 to June 1958. The change in rate of recovery on the fishing grounds reflects, in part, the decrease in fishing effort and the fact that groups of tags put on most recently have less chance of being recovered.

Table 3 shows the numbers of shrimp tagged by sizes, from December 3, 1957 to June 24, 1958 at Flamingo (Coot Bay), Bahia Honda Key (Marathon) and at Tortugas, together with the recoveries of Tortugas shrimp.

One shrimp from the experiment at Flamingo (Coot Bay) was recovered just north of Key West on the Tortugas grounds. The shrimp had been out 123 days and had travelled about 60 miles in a straight line distance from where it had been tagged. It had grown from 21 millimeters carapace length to 32 millimeters (about a 100 count as compared to 36 count, heads off). The importance of this recovery lies in the support it provides to the theory that the Everglades National Park estuary is the nursery ground which supplies the Tortugas grounds.

To date no recoveries have been reported from the Bahia Honda tagging.

The analysis of percentage of recoveries by size of shrimp from the Tortugas experiments (Table 3) is of interest, since these data show that the smaller shrimp (below 30 millimeters carapace length) have a lower rate of recovery than the larger shrimp. That tagging mortality is likely higher for the smaller shrimp is in agreement with the findings of Lindner and Anderson (1956) who examined the recoveries of tagged white shrimp by size.

There is approximately the same or perhaps a higher percentage of recoveries by size groups as the size increases (above about 30 millimeters carapace length). This latter result suggests that the larger shrimp are not migrating out of the fishing grounds to a significant extent, which in turn means that the problem of emigration may not be an im-

TABLE 2.—*Summary of shrimp tagging experiments*

Method of capture	Area tagged	Date tagged	Number tagged	Number recovered by June 24, 1958	Percentage recovered by area
Try net and standard trawl by Key West shrimp boats	Commercial fishing grounds; wreck buoy to Dry Tortugas	December 17-19, 1957	364	108	29.6
		December 27-29, 1957	327	86	26.2
		February 26-27, 1958	145	35	24.1
		June 9-10, 1958	134	8	5.9
Try net towed by outboard motor and skiff	Marathon (northwest of Bahia Honda bridge)	January 28, 1958	97	0	—
Night dip net and channel net	Flamingo (Everglades National Park)	December 16, 1957 to March 15, 1958	1157	1	—

TABLE 3.—*Number of shrimp tagged and percentage recovered, according to size when tagged*

[Tortugas and Florida Bay, December 3, 1957 to June 24, 1958]

Carapace length (centimeters)	Number tagged by areas			Tortugas recoveries	
	Flamingo[1] (Coot Bay)	Bahia Honda (Marathon)	Tortugas	Total	Percentage
1.0	—	1	—	—	—
1.2	—	0	—	—	—
1.4	2	2	—	—	—
1.6	56	14	—	—	—
1.8	185	27	—	—	—
2.0	142	25	16	1	6.3
2.2	65	13	92	16	17.4
2.4	23	10	145	25	17.2
2.6	7	2	160	37	23.1
2.8	1	0	130	41	31.5
3.0	3	3	132	26	19.6
3.2	3	—	89	27	30.3
3.4	—	—	55	18	32.7
3.6	—	—	47	18	38.2
3.8	—	—	29	5	17.2
4.0	—	—	20	7	35.0
4.2	—	—	16	6	37.5
4.4	—	—	5	2	40.0
4.6	—	—	8	4	50.0
4.8	—	—	4	0	0.0
5.0	—	—	4	1	25.0
5.2	—	—	1	0	0.0
5.4	—	—	2	1	50.0
Total	487	97	955	235	

[1]676 were also tagged but not measured or sexed.

portant source of error in future studies of mortality, using either the tagging method or catch-per-unit-of-effort data.

The results of tagging experiments can be misleading if the tagging locations or the fishing effort devoted to recovery of tagged animals is not well distributed throughout the fishery. The numbers of shrimp tagged and recovered have been plotted by 10-mile squares for the period December 1957 to June 1958 (Figure 5). The over-all recovery rate for the grounds during this period was 24 percent. It can be seen from the figure that the effort devoted to tagging is fairly well distributed on the grounds and that the rate of recovery in each location is generally close to the average figure of 24 percent.

GROWTH

At the time of tagging a measurement is made of the carapace length, and the sex and date released are recorded for each shrimp. Hence, when recoveries are made and the whole shrimp is returned, with the date captured being recorded, information on growth is available.

An important consideration in our estimates of growth from tagged shrimp is the possible shrinkage due to preservation. At the time of tagging the shrimp is measured alive but when recaptured is preserved in formalin. It was assumed that there was no measurable shrinkage in carapace lengths due to preservation because Lindner and Anderson (1956) found no shrinkage in total length of white shrimp *(P. setiferus)*.

Using the data gathered from December 1957 to April 1958 an estimate of winter growth was made. These data have been grouped by the average number of days the tagged shrimp were free, and are presented separately for males and females. The average increase in carapace length is plotted in Figure

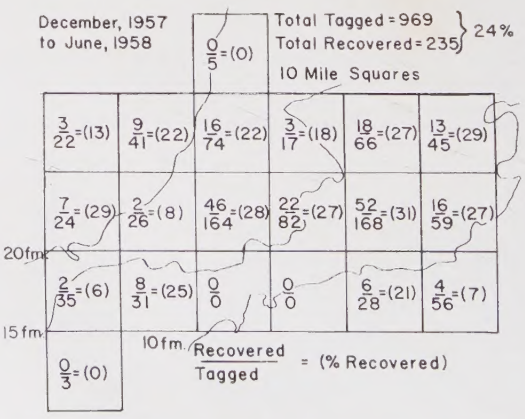

FIGURE 5.—Map showing Tortugas fishing grounds, and releases and recoveries of tagged shrimp. (The 10-mile squares include boundary of fishing area.)

6. Females increased from 31 millimeters to 34 millimeters carapace length (39 to 31 count, heads off) in 45 days, or about 2 millimeters (5 counts) per month. The males were smaller on the average and increased from 26 millimeters to 28 millimeters carapace length (60 to 50 count, heads off) in 45 days, or about 1.5 millimeters (7 counts) per month.

This growth was made in the unusually cold winter of 1957-58 and may be slower than the growth in a more normal winter.

MIGRATION

At the time of release of tagged shrimp the area of tagging and the date are recorded. It is thus possible to obtain information on the direction and rate of movement, provided the date of capture and area of capture of tagged shrimp are accurately recorded by the fishermen.

Release positions of tagged shrimp on the fishing grounds were found by dead reckoning. The tagging vessels were not out of sight of the visual navigational aides located on the southern part of the grounds for extended periods. This permitted frequent checks on position and verification of the location of tagging positions.

In some cases recovery locations were not as exact as was desired, but experience has shown that the fishermen have a good idea of their approximate position and a good deal of reliance can be placed on most reported locations. This is demonstrated by recovered shrimp that have been at liberty for only a short time; fishermen have usually reported catching these shrimp very near to the point of release.

To illustrate the distance shrimp moved during the period December 1957 to June 1958, Table 4 was prepared. The recoveries are reported by sexes separately, according to the distance travelled in 10-mile groups. Recoveries are also listed by the number of days at liberty, for presumably the more time free the greater distance they would be able to travel. Totals are also provided for each "days free" grouping for both sexes, and distance travelled for each sex. The majority of recoveries were made within less than 10 miles from the point of tagging; this distance in-

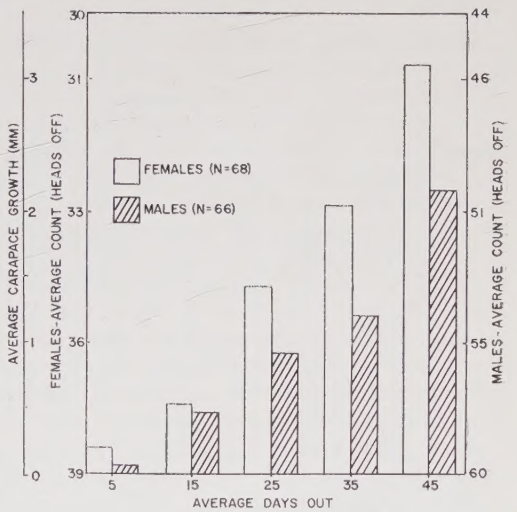

FIGURE 6.—Average growth of tagged shrimp, Tortugas, December 1957 to April 1958.

TABLE 4.—*Movements of tagged shrimp, Tortugas, December 1957 to June 1958*

Days free (10-day intervals)	Minimum miles moved (10-mile intervals)									Males and females	
	Females				Males					Total	Percentage
	1-10	11-20	21-30	Total	1-10	11-20	21-30	31-40	Total		
0- 10	14	4	–	18	12	1	–	–	13	31	19.5
11- 20	14	3	1	18	16	6	1	–	23	41	25.8
21- 30	15	6	1	22	7	1	1	–	9	31	19.5
31- 40	5	2	2	9	7	1	–	–	8	17	10.7
41- 50	7	1	1	9	5	1	1	–	7	16	10.1
51- 60	1	1	1	3	1	–	–	1	2	5	3.1
61- 70	1	–	–	1	2	–	1	–	3	4	2.5
71- 80	1	3	1	5	2	–	–	–	2	7	4.4
81- 90	2	1	–	3	–	–	–	–	–	3	1.9
91-100	1	–	–	1	–	1	–	–	1	2	1.3
101-110	–	1	–	1	–	–	–	–	–	1	0.6
111-120	–	–	–	–	–	–	–	–	–	–	0.0
121-130	–	–	–	–	–	–	–	–	–	–	0.0
131-140	–	–	–	–	–	–	–	–	–	–	0.0
141-150	–	–	–	–	1	–	–	–	1	1	0.6
Total	61	22	7	90	53	11	4	1	69	159	
Percentage	68	24	8	100	77	16	6	1	100		100.0

cluded 68 percent of the recovered females and 77 percent of the recovered males. The majority of recoveries of both sexes were made within 50 days and the distribution of days free for each sex is about the same.

The general trend of direction the shrimp moved was ascertained by noting the recovery position in relation to the tagging position and grouping these movements by the four quadrants of the compass: north to east, east to south, south to west, and west to north. Only recoveries caught at distances greater than 5 miles from the tagging locations have been used. The numbers of recovered shrimp falling into each category are shown in Table 5, separately for four periods at liberty: 0-20, 21-40, 41-60, and 61-80 days.

The movements of shrimp in some locations may be restricted somewhat, perhaps because of depth of water or the presence of other geographic barriers. For example, shrimp tagged on the western limit of the grounds may move in a more westerly direction rather than a northwestern direction because of deep water. Shrimp tagged on the northern portion of the grounds may tend to move due west because of undesirable bottom. Because the location of tagging can have an effect, it is best to examine the results in general terms. The lowest number of recoveries generally occurred in the southeast quadrant, suggesting that the movement is mainly north and west.

It is concluded that since these recoveries are from all over the grounds and that errors in plotting recovered shrimp are likely random, that the net movement of shrimp is generally northwesterly on the Tortugas grounds.

ACKNOWLEDGMENTS

Appreciation is extended to the many shrimp dealers who have permitted access to their business records and given freely of their time. We are also indebted to the many fishermen who have donated their time and services. Members of The Marine Laboratory of the University of Miami who have assisted in the gathering and processing of information in this report include Alfred V. Volpe, Richard Zeigenfuss, James Murdock, James Regan, Edward Klima, Howard Foulk, and Mrs. Edwin S. Iversen. William Anderson and Donald Allen of the U. S. Fish and Wildlife Service read and criticized the manuscript of this report.

TABLE 5.—*Migration of 100 tagged Tortugas shrimp, December 1957 to April 1958*

Time free	Direction moved and number	
	NW / SW	NE / SE
0-20 days	11 / 12	11 / 9
21-40 days	13 / 7	10 / 3
41-60 days	7 / 3	4 / 3
61-80 days	2 / 3	2 / 0

LITERATURE CITED

HIGMAN, JAMES B. 1952. Preliminary investigation of the live bait shrimp fishery of Florida Bay and the Keys. The Marine Lab., Univ. of Miami, (mimeographed), 8 pp.

IDYLL, C. P. 1957. The commercial shrimp industry of Florida. Florida St. Bd. Cons., Univ. Miami Mar. Lab., Educ. Ser. 6, 28 pp. (Originally issued March 1950, re-issued August 1957.)

LINDNER, MILTON J. AND WILLIAM W. ANDERSON. 1956. Growth, migrations, spawning and size distribution of shrimp, *Penaeus setiferus*. U. S. Fish and Wildl. Serv., Fish. Bull. 106: 555-645.

SIEBENALER, J. B. 1952. Studies of "trash" caught by shrimp trawlers in Florida. Proc. Gulf and Carib. Fish. Ins., 4th Annual Session: 94-99.

WILLIAMS, AUSTIN E. 1955. A contribution to the life histories of commercial shrimps *Penaeidae* in North Carolina. Bull. Mar. Sci., Gulf and Carib., 5 (2): 116-146.

WOODBURN, K. D., BONNIE ELDRED, EUGENIE CLARK, ROBERT F. HUTTON AND ROBERT M. INGLE. 1957. The live bait shrimp industry of the west coast of Florida (Cedar Keys to Naples). Florida St. Bd. Cons., Tech. Ser. 21, 33 pp.

Observations on the Ecology of Epinepheline and Lutjanid Fishes of the Society Islands, with Emphasis on Food Habits[1]

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ABSTRACT

Food habits and habitats frequented by several groupers (Epinephelinae) and snappers (Lutjanidae) of the Society Islands were investigated preliminary to the introduction into Hawaiian waters from French Oceania of selected inshore marine fishes of food and sport-fishing value. Fifteen species of groupers and 14 snappers which do not occur in the Hawaiian chain were collected in Tahiti and Moorea. Stomach contents of 1,305 specimens of 16 species were examined. Of these, 1,131 were from the snapper, *Lutjanus vaigiensis*, and the two groupers, *Epinephelus merra* and *Cephalopholis argus*, these three species being the most important market fishes of these two groups in Tahiti. *E. merra* is common in lagoons, and about two-thirds of the specimens had fed on benthic crustaceans (principally crabs) and the rest mostly on fishes. During the southern summer, however, when juvenile fishes were abundant on the reefs, fish made up three-fourths of the diet. *C. argus* is the dominant carnivorous fish on outer reefs but is also found in lagoons. More than three-fourths of the stomachs of this species contained fishes and the rest benthic crustaceans. *L. vaigiensis*, also a fish of diverse habitats, consumes fishes and crustacea in about equal amounts. Very few of the fishes found in the stomachs of these three species are of commercial importance.

INTRODUCTION

The most striking feature of the Hawaiian inshore fish fauna is the almost complete lack of groupers (Subfamily Epinephelinæ, Family Serranidæ) and snappers (Lutjanidæ). Elsewhere in the tropical Pacific, fishes of these two large groups assume dominant roles in the reef environment, and many of the species are important food fishes.

Why such fishes are scarce in the Hawaiian chain is not known. As pointed out by Gosline (1955), the presence of 15 species of *Epinephelus* and 14 species of *Lutjanus* in Japan would seem to rule out the possibility that shallow water serranids and lutjanids cannot exist in Hawaii because of cool water temperatures. Surface temperatures of the sea off southern Japan are at least as low as those of Hawaii. No limiting factor is apparent among the ecological conditions in Hawaii. Suitable food appears to be present. Small reef fishes, such as surgeonfishes (Acanthuridæ), damselfishes (Pomacentridæ), and wrasses (Labridæ), as well as small crustacea abound, but carnivorous fishes of moderate size are not abundant. Probably the lack of snappers and groupers in the Hawaiian Islands is related to the great distances separating these islands from other island groups where these fishes occur, coupled with unfavorable direction of currents. There is also the possibility that epinepheline and lutjanid fishes have a relatively short planktonic life. If such fishes are missing from the Hawaiian fish fauna because of distance and currents alone, then the successful introduction of them would seem to depend only upon the selection of desirable species and transportation of sufficient numbers of them to Hawaiian waters. A major consideration in assessing the desirability of such species is their food habits, since this determines the impact they may have on the present marine life of Hawaii. Although groupers and snappers are known to be, in general, non-specialized carnivores, little information is available on the specific food of the species of the tropical Pacific. It was

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therefore deemed prudent to investigate the food habits of the species being considered for introduction.

The introduction program was initiated by the junior author, then the Director of Fish and Game, Territory of Hawaii, and after the present study was completed, a large-scale attempt was made to transplant several species of groupers and snappers from French Oceania to the Hawaiian Islands. An article dealing with the introduction of aquatic organisms, including groupers and snappers, to Hawaii will soon appear (Randall, in press).

COLLECTION OF MATERIAL

The Society Islands were chosen as the site for the food-habit study because they are high islands and the surface temperatures of adjacent seas approximate those of Hawaii. These islands are also within the sphere of operations of the Pacific Oceanic Fishery Investigations of the United States Fish and Wildlife Service at Honolulu. A disadvantage of this region with respect to its potentiality as a site from which to obtain fishes for introduction is the somewhat depauperate nature of the fish fauna as compared to areas in the western tropical Pacific. The list of groupers and snappers taken by us in the Society Islands does not include all of these fishes which occur there. For example, at least one species of giant grouper, or jewfish, is known in Tahiti, but was not collected. But the list for the Society Islands is nearly complete and certainly some of the epinepheline and lutjanid fishes commonly seen about islands in more western Pacific areas are absent.

Because of the possibility that food habits might change with the seasons, stomach contents were examined throughout the year. Change in the diet was manifest in a larger percentage of small fishes found in the stomachs during the southern summer when there is an abundance of juvenile fishes on the reefs. The senior author obtained information on food habits from February 24, 1956, to May 7, 1957. The junior author, with the assistance of Carl Nemoto, carried out field work for 6 weeks beginning July 27, 1956.

Emphasis in the study was placed on the two most common groupers *(Epinephelus merra* and *Cephalopholis argus)* and the most common snapper *(Lutjanus vaigiensis)*. The abundance of these species in Tahitian waters despite considerable fishing effort, their value as food fishes, and their lack of strong toxic qualities (unlike occasional specimens of *Lutjanus monostigmus, Lutjanus bohar, Lutjanus rivulutus, Lethrinus miniatus,* and *Plectropomus leopardus)* made them likely prospects for introduction. Randall (1958) has presented a review of ciguatera (tropical fish poisoning) and a discussion of the relative toxic properties of groupers and snappers.

Most specimens of which stomach contents were examined were collected by spearing. Some fishes were obtained by poisoning with Noxfish, a commercial preparation containing 5 percent rotenone. All freshly ingested food items in fishes taken by poisoning had to be disregarded, for these were probably prior victims of the poison and may not have represented normal prey. A few fishes were taken by hook and line. It was difficult to obtain large numbers of *L. vaigiensis* by spearing, so examination was also made of specimens obtained by Tahitian fishermen in a large stone trap. Stomachs of many of these trapped fish were empty.

Special attention was given to the identification of fishes found in the stomachs in an effort to determine any possible predilection of the groupers and snappers to prey upon economically important species present in Hawaiian waters. Lengths of fishes in identifiable condition in the stomachs were usually taken, but volume measurements were not made. Organisms other than fishes were usually not identified to species. For computing gross percentages of food items by major animal groups (such as fishes, crustacea, mollusks) a fish which had consumed animals belonging to two or more groups was assigned to that group which was represented by the greatest amount of food in the stomach.

Most of the grouper and snapper stomachs were empty. Furthermore, the majority of the fishes found in the stomachs were unidentifiable due to digestion, and the number of specific identifications was disappointingly few.

TAXONOMIC AND ECOLOGICAL NOTES

The following list contains those groupers and snappers that were collected in the Society Islands but which are not known to be native to Hawaiian waters. The work of Schultz *et al.* (1953) on fishes of the Marshall and Mariana

Islands was the principal identification reference. Some taxonomic information is included in the following paragraphs for those species which might be confused with others. All lengths of fishes given are standard length. A large collection of these and other fishes of the Society Islands has been deposited in the Natural History Museum of Stanford University. Most fishes were taken at the islands of Moorea and Tahiti. An asterisk indicates that information on food habits was obtained.

SERRANIDAE

EPINEPHELINAE

**Epinephelus merra* Bloch
**Epinephelus hexagonatus* (Bloch and Schneider)
**Epinephelus elongatus* Schultz
**Epinephelus fasciatus* (Forskål)
**Epinephelus fuscoguttatus* (Forskål)
**Cephalopholis argus* (Bloch and Schneider)
**Cephalopholis urodelus* Bloch and Schneider
**Cephalopholis miniatus* (Forskål)
**Cephalopholis leopardus* (Lacépède)
**Variola louti* (Forskål)
**Plectropomus leopardus* (Lacépède)
Plectropomus maculatus (Bloch)

LUTJANIDAE

**Lutjanus vaigiensis* (Quoy and Gaimard)
**Lutjanus kasmira* (Forskål)
**Lutjanus monostigmus* (Cuvier and Valenciennes)
**Lutjanus gibbus* (Forskål)
Lutjanus rivulatus (Cuvier and Valenciennes)
Lutjanus bohar (Forskål)
**Lethrinus miniatus* (Bloch and Schneider)
Lethrinus variegatus Cuvier and Valenciennes
Gnathodentex aureolineatus (Lacépède)
Plectorhinchus orientalis (Bloch)
**Pterocaesio tile* (Cuvier and Valenciennes)

Of the foregoing species, *Epinephelus fuscoguttatus*, *Lutjanus bohar*, and *Lethrinus* spp. are much commoner in the low-lying Tuamotus than in the Societies. It is not known whether this difference in abundance reflects a dependence on marine habitats associated with low islands or whether the populations of these species are reduced more readily by the heavier fishing around Moorea and Tahiti. Wheeler (Wheeler and Ommanney, 1953, p. 31 and table opposite p. 56) noted that *Lutjanus civis*, which is apparently synonymous with *L. bohar*, is rare at the high island of Mauritius, but is common off such low islands as the Seychelles, Amirante Islands, and Chagos Archipelago.

Great variation was noted in the size of food organisms in the stomachs of these predatory fishes, especially the groupers. A 231-millimeter *Cephalopholis argus* contained a 203-millimeter *Decapterus pinnulatus*. A 191-millimeter specimen of *E. merra* contained an 80-millimeter *Acanthurus lineatus* (body depth, 38 millimeters). Other specimens of *C. argus* and *E. merra* of about the same size had fed upon crabs as small as 5 to 10 millimeters (transverse measurement of the carapace). The most surprising example of a large grouper eating small prey was that of a 378-millimeter specimen of *Cephalopholis miniatus* whose entire stomach contents consisted of nine small palæmonid shrimps averaging about 10 millimeters from rostrum to abdominal flexure.

More fishes with full stomachs could usually be found in the morning than in the afternoon. For example, of 200 specimens of *Epinephelus merra*, 43.8 percent taken in the morning before 11 a.m. contained food, but only 29.4 percent of those taken in the afternoon after 1 p.m. contained food. For 59 specimens of *Lutjanus vaigiensis*, taken by spearing, the percentages are even more diverse; 59.5 percent of the stomachs from fish taken in the morning hours contained food, as contrasted to 17.6 percent for the afternoon. Even in the early morning hours the stomach contents of this snapper were often not identifiable, indicating considerable feeding at night. Nocturnal feeding has been reported previously (Longley and Hildebrand, 1941, pp. 115-119) for the snappers *Lutjanus griseus* (Linnæus), *Lutjanus apodus* (Walbaum), and *Lutjanus analis* (Cuvier and Valenciennes) at Tortugas, Florida. It is certain, however, that *L. vaigiensis* is not entirely nocturnal in its feeding, for stomach contents of specimens taken during daylight hours have sometimes been fresh enough to indicate recent ingestion. These fish can also be caught by hook and line during the day, although not as readily as groupers. On one occasion a small adult fish was seen to capture a crustacean at about 2 p.m. Although primarily diurnal the groupers in Tahitian waters may feed nocturnally, especially on bright moonlight nights.

During spawning very few grouper stomachs contained food, and at this time fishermen could not catch these fishes with hook and line. Some took them by spearing, which they said was easier at this time. *Epinephelus merra* was found to spawn in Tahiti over a period of 3 to 4 days once each month from January to April. The peak of spawning occurred 2 to 3 days before full moon. *Lutjanus*

vaigiensis also appears to spawn at about the time of full moon. Adults examined on October 10 (21 fish), October 13 (53 fish), and October 16 (42 fish) revealed ripe gonads and no spent fish. However, on October 20, the day after full moon, 56 specimens were examined, 35 of which were females, and all but four of the females had recently spawned. The few observations on spawning from November through March suggest that during these months spawning also takes place near the time of full moon. No information on the reproduction of *L. vaigiensis* was obtained for the period from April to October.

FEEDING HABITS AND LIFE HISTORY NOTES BY SPECIES

Epinephelus merra
(Tahitian name: *tarao*)

This grouper abounds in shallow water off Tahiti about coral heads in the lagoon. The greatest depth at which it was observed was 90 feet. It was never seen outside the barrier reef. The average length of fish from the Papeete market was about 185 millimeters. The largest specimen taken in Tahiti (a male) was 254 millimeters long. Males attain greater length than females (largest female seen, 209 millimeters) and are of larger average size.

Stomachs of 481 adults of *E. merra* were opened immediately after capture, and 296 were empty. Crustaceans represented 67.6 percent of the food in the stomachs during the two periods February 24, 1956-December 26, 1956, and March 23, 1957-May 5, 1957, 28.7 percent was fish, and 3.7 percent mollusk. During the period December 26, 1956-March 19, 1957, the percentage of fish rose to 74.6 because of the appearance of great numbers of juvenile fishes on the reefs, especially the acanthurid *Ctenochaetus striatus* (Quoy and Gaimard) and the teuthidid *Teuthis spinus* (Linnæus). This percentage, however, is probably higher than is representative of this period, for two periods of heavy sampling of this grouper coincided with a tremendous concentration of postacronurus stages of *C. striatus*.

Of the crustacea in the stomachs of *E. merra*, 72.2 percent were crabs (primarily xanthids and portunids) and 21.1 percent were shrimps (mostly alpheids). One 158-millimeter grouper had eaten two *Stenopus* measuring 35 millimeters from rostrum to abdominal flexure and had swallowed them with all the long appendages intact. Stomachs of five specimens contained stomatopods, and one a small galatheid. Of the four stomachs containing mollusks, two had small octopods; one had five small rock oysters; and one had a gastropod *(Hydatina)*.

The following fishes were taken from the stomachs of *E. merra*. In parentheses after each name is the number of fishes found in the stomachs and, when measured, the standard lengths.

Synodus variegatus (1: 41 millimeters)
Gymnothorax gracilicauda (1)
Gymnothorax sp. (1: 120 millimeters)
Holocentrus microstomus (1: 55 millimeters)
Holocentrus sp. (1: 30 millimeters)
Corythoichthys flavofasciatus (1)
Apogon snyderi (2: 30 and 32 millimeters)
Apogon exostigma (1: 37 millimeters)
Pomacentrus nigricans (1: 22 millimeters)
Halichoeres trimaculatus (1:90 millimeters)
Scarus sordidus (1: 40 millimeters)
Fusigobius neophytus (1: 23 millimeters)
Asteropteryx semipunctatus (1: 30 millimeters)
Acanthurus lineatus (2: 40 and 80 millimeters)
Acanthurus triostegus (2: 26 millimeters)
Acanthurus sp. (2: 25 millimeters)
Ctenochaetus striatus (51: 29 to 45 millimeters)
Naso sp. (1: juvenile)
Acanthurid (1)
Teuthis spinus (10: 30 to 40 millimeters)
Teuthis rostratus (1: 52 millimeters)
Balistid (1: 19 millimeters)
Canthigaster sp. (3: 22 to 23 millimeters)

All the foregoing species are of little commercial importance.

Epinephelus hexagonatus
(Tahitian name: *tarao a'au*)

This grouper is similar to *Epinephelus merra*, and the two have at times been erroneously considered to be the same species. The differences between the two can be seen from the illustrations of Schultz *et al.* (1953, pls. 25 and 26). The brown spots on the body of *E. merra* are discrete, whereas those of *hexagonatus* are close together, merging on six sides to leave a small white spot at each corner. *E. hexagonatus* may be further distinguished by a grouping of spots to form four large dark areas along the back at the base of the dorsal fin, by a roundish olivaceous blotch behind the eye, and by a similar, horizontally-elongated blotch on the operculum. Specimens of *E. hexagonatus* from the Society Islands had 18 or 19 pectoral rays and 23 to 25 gill

rakers, and specimens of *E. merra* 17 or 18 pectoral rays and 20 to 23 gill rakers (counting all rudiments).

E. hexagonatus, like *E. merra*, is a shallow water species. It is most commonly found outside the barrier reef, although it may be taken on reefs in lagoon or bay areas. However, the latter areas are usually subject to some wave action. *E. hexagonatus* is a small grouper and appears to average only slightly larger than *E. merra*.

Twenty-two stomachs were opened, of which 16 were empty. Three of the stomachs containing food had fish and three had crustaceans (two of them crabs).

Epinephelus elongatus
(Tahitian name: *faroa*)

This uncommon grouper is a pale, brown-spotted fish resembling *E. merra* and *E. hexagonatus*. It may be differentiated from them by usually possessing 15 instead of 16 dorsal soft rays, 27 to 30 gill rakers, and having a more elongate body (depth 3.3 to 3.7 in standard length in contrast to 3.2 to 3.3 for the other two species). It also attains greater size. Of the 12 specimens collected, the longest was 498 millimeters. Although *E. elongatus* may be found in water as shallow as 10 feet, it more often occurs at greater depths. The greatest depth at which it was observed was 150 feet, but few observations were made in deeper water. This species appears to be more common in outer reef areas than in lagoons.

Of three stomachs with food all contained fish remains and one also had a crab chela.

Epinephelus fasciatus
(Tahitian name: *matapuu*)

This species was seen only occasionally outside the barrier reef at depths greater than 50 feet. Few specimens were taken, and all had empty stomachs.

Epinephelus fuscoguttatus
(Tahitian name: *atara*)

Rare in Tahiti, this grouper is common in shallow water in the Tuamotus where 33 specimens were obtained. The largest was 402 millimeters in length. Stomachs of 10 specimens contained food: four had crab remains (two, only the chela of a large crab); one contained a small shrimp, and the remaining five had fish, one of which was an unidentified eel. *E. fuscoguttatus* was the least wary of the serranids observed. It occasionally struck at fish impaled on a spear and would take fish from the outstretched hand of a swimmer.

Cephalopholis argus
(Tahitian name: *roi*)

This dark, blue-spotted fish and *E. merra* are the commonest groupers of the Society Islands and those of greatest commercial importance. *C. argus* appears to be the dominant piscivorous fish outside the barrier reef in water of 10 to 100 feet or more. It is also abundant throughout lagoons and bays, wherever there is coral and rock shelter. It attains a length of about 400 millimeters, but individuals longer than 300 millimeters are uncommon.

Of 280 specimens obtained for food study, the stomachs of 182 were empty. Of stomachs with food, 77.5 percent contained fish and 22.5 percent crustacea. Of the crustacea, 42.8 percent were shrimps (primarily alpheids), 33.2 percent crabs (xanthids, grapsoids, and portunids), and 14.3 percent were stomatopods. One *C. argus* stomach contained a galatheid. Of four juveniles 41 to 50 millimeters in length, three had eaten shrimps, and the fourth two small fish and a crab leg.

The following fish were identified from the stomachs of adult *C. argus:*

Decapterus pinnulatus (1: 203 millimeters)
Pseudogramma polyacantha (1: 45 millimeters)
Apogon snyderi (4: 30 millimeters)
Apogonid (1: 25 millimeters)
Pterocaesio tile (1: 62 millimeters)
Parupeneus sp. (1: 35 millimeters)
Pomacentrid (2: 15 millimeters)
Pseudocheilinus hexataenia (4: 24 to 39 millimeters)
Stethojulis axillaris (1: 78 millimeters)
Paracirrhites arcatus (1: 63 millimeters)
Eleotrid (1: 16 millimeters)
Gnatholepis knighti (1: 27 millimeters)
Cirripectus variolosus (1: 38 millimeters)
Tripterygiid (1: 13 millimeters)
Acanthurus triostegus (1: 25 millimeters)
Ctenochaetus striatus (11: 29 to 50 millimeters)
Teuthis spinus (1: 35 millimeters)
Monocanthid (1)
Balistapus undulatus (1: 70 millimeters)
Balistid (1: 30 millimeters)

About half of the specimens of *C. argus* examined were taken from outer reefs and half from protected waters. The kinds of fish preyed upon differed greatly with the habitat. *Pseudocheilinus hexataenia*, *Cirripectus*

variolosus, and *Paracirrhites arcatus*, all abundant outside the barrier reef but not in the lagoon environment, were found in the stomachs of groupers taken from the reef. In the lagoon the principal fishes in the stomachs were *Apogon snyderi*, *Gnatholepis knighti*, and *Teuthis spinus*. With the exception of *Decapterus pinnulatus* the fishes found in the stomachs of *C. argus* are of little commercial importance.

Cephalopholis urodelus
(Tahitian name: none or *rero*)

This is a red fish with two oblique white bands on the caudal fin. It is most common in outer reef areas but is also frequently encountered in lagoons. The largest of 71 specimens speared measured 187 millimeters in length. Like *C. argus* it is principally piscivorous; 68 percent of the 25 stomachs with food contained fish, and the rest crustacea. Three of the stomachs contained crabs; three, shrimps; one, a stomatopod; and one, an unidentifiable crustacean. Fishes identified from the stomachs are: *Holocentrus sammara* (1: 48 millimeters); *Holocentrus* sp. (1: 35 millimeters); *Acanthurus* sp. (3 acronuri: 25 millimeters); *Ctenochaetus striatus* (5 acronuri and postacronuri: 35 millimeters); and *Cirripectus variolosus* (1: 40 millimeters).

Cephalopholis miniatus
(Tahitian name: *rero*)

This colorful grouper (red with brown bars and small blue spots) is a bay and deep lagoon form. The largest specimen, collected at a depth of 110 feet in Papetoai Bay, Moorea, measured 378 millimeters in length. Of the groupers in the Society Islands, this is the most highly esteemed as food. Unfortunately, it is not common.

Forty-eight adults were obtained, 24 of which had empty stomachs. Ten of the stomachs contained fishes; one, small palaemonid shrimps; one, a *Stenopus* chela; and one, a 10-millimeter stone. Of the fishes taken from stomachs, the following were identified: *Apogon snyderi* or *A. exostigma* (2: 30 and 42 millimeters); *Apogon* sp. (2: 50 and 78 millimeters); *Anthias sp.* (1: 70 millimeters); acanthurid (1: 40 millimeters); and *Canthigaster margaritatus* (2: 25 and 30 millimeters).

In Papetoai Bay, Moorea, and in the lagoon near the entrance to the bay, sections of coral become detached from the shore reef and roll into deeper water (50 to 100 feet or more) where they are isolated by stretches of mud or mud-sand and form a discrete little community. The dominant small fishes of this community are a species of *Apogon* and a species of *Anthias*, both of which are apparently undescribed. Other small fishes found here are *Apogon exostigma*, *Apogon snyderi*, juvenile *Pterocaesio tile*, juvenile *Lutjanus kasmira*, and juvenile *Acanthurus mata*, *A. thompsoni*, and *A. bleekeri*. The dominant piscivorous fish in this community is *Cephalopholis miniatus*.

Cephalopholis leopardus
(Tahitian name: none or *rero*)

A small fish that is uncommon in the Society Islands. Few specimens were taken. One had eaten a fish.

Variola louti
(Tahitian name: *hoa*)

This fish is not common and is found in passes and outside the barrier reef, usually at depths greater than 60 feet. It attains a length of at least 400 millimeters. Of seven stomachs that were opened, five were empty and two contained digested fish.

Plectropomus leopardus
(Tahitian name: *tonu*)

An uncommon and moderately large grouper that is red with small dark-edged blue spots. It grows to about 1,000 millimeters in length and was encountered most frequently in passes but was seen in both lagoon and outer reef areas. This species and *Variola louti*, unlike the other groupers, were usually observed several feet off the bottom instead of hiding in holes in the coral. However, *P. leopardus* does seek refuge in caves.

Seven specimens were collected, the largest 888 millimeters in length. Four stomachs were empty; one contained fish bones and scales; another had a 150-millimeter *Gomphosus varius*; and one, a 138-millimeter *Acanthurus gahhm*.

Plectropomus maculatus
(no Tahitian name)

This species is rare in Tahiti and was seen only in deeper parts of the lagoon. Three specimens were collected, all white with black saddles on the back and a yellow caudal peduncle and fin. The dorsal fin formula is VIII, 11.

Lutjanus vaigiensis
(Tahitian name: *toau*)

This is the most common snapper in Tahitian waters and is a valuable food fish. It is more often seen in lagoon and bay areas than on the outer reef. It occurs in brackish water over mud bottom or in regions of clear water and much living coral. Usually it is found in water shallower than 60 or 70 feet. Often large aggregations, less compact than schools, are encountered. The young are common in inshore waters, often where it is somewhat muddy.

In all, 370 specimens were obtained, the largest measuring 252 millimeters in length. Three-fourths of these were captured in a large Tahitian stone trap and all but 14 of these had empty stomachs. Of the remaining 98 fish, taken primarily by spearing, 53 had empty stomachs.

Of the stomachs of adults with food, 54.3 percent contained crustacea and 42.4 percent fish. Of the crustacea, 64 percent were crabs (xanthids, portunids, maiids, juvenile pagurids, and ocypodids), 17 percent shrimps, and 4 percent stomatopods (the remaining crustacea unidentified). Fishes in stomachs that were identified are: *Holocentrus sammara* (1: 40 millimeters); *Acanthurus triostegus* (1 acronurus: 21 millimeters); *Ctenochaetus striatus* (4 acronuri: 35 to 40 millimeters); and *Teuthis* sp. (1: 30 millimeters). One stomach contained a balanoglossid worm, and one, a large piece of tunicate. Another contained insect remains in addition to a shrimp. Randall (1955, p. 91), who examined stomachs of eight specimens from the Gilbert Islands, reported one fish which had eaten a small holothurian.

Five or six juveniles, 62 to 72 millimeters in length, which were collected at night, contained tiny crabs, unidentified eggs, and fish offal. Four of six larger specimens, 100 to 118 millimeters in length, also taken at night, had eaten small crabs, alpheid shrimps, and unidentified crustacea.

Judging from the catch of a fixed stone trap, some migration or movement of this snapper must take place. Groupers on the other hand were rarely taken in the trap.

Lutjanus kasmira
(Tahitian name: *taape*)

A distinctive species, yellow with lengthwise blue stripes, this snapper is common in lagoons where it seems to prefer water slightly deeper than that frequented by *L. vaigiensis*. It is of somewhat smaller average size than *vaigiensis*. The largest specimen taken was 225 millimeters long. It is frequently seen in small schools.

Seventeen stomachs were opened, eight of which were empty. Five stomachs contained fish (one of these also had a crustacean appendage); one stomach contained a crab; one, a shrimp; and two, unidentified crustaceans. The stomach of one 155-millimeter specimen contained three acronuri of *Ctenochaetus striatus*, about 40 millimeters long, and one 45-millimeter juvenile of this surgeonfish.

Lutjanus monostigmus
(Tahitian name: *taivaiva*)

The most characteristic marking of this snapper, a larger species than the preceding two, is a single black spot on the side. The length of the largest specimen taken was 360 millimeters. *L. monostigmus* is found in the lagoons, passes, and occasionally in deeper outer reef zones. It is often a resident of caves. Although solitary fish may be encountered, more frequently this species is found in small groups. Occasionally large schools are seen.

Thirty-two stomachs were opened, 18 of which were empty. The rest contained fishes. Only the following three species of fish could be identified from the stomachs: *Decapterus pinnulatus*, *Selar crumenophthalmus*, and *Ctenochaetus striatus*. The first mentioned carangid was found in two specimens from the Tuamotus; one 295-millimeter snapper contained three, 70 to 133 millimeters in length, and one 325-millimeter fish contained two about 100 millimeters long. Six acronuri and postacronuri of *C. striatus* were identified among eight small fishes found in the stomach of a 318-millimeter *L. monostigmus* from Moorea.

Lutjanus gibbus
(Tahitian name: *tuhara*)

This red species is less common in the Society Islands than the snappers already discussed, although occasionally large schools may be observed in passes or outside the barrier reef in 40-50 feet or more of water. Solitary adults or small groups of adults are sometimes seen in bays or lagoons. The largest specimen obtained was 358 millimeters in length.

Twenty-three specimens were collected, only nine of which had food in their stomachs. Five of these were juveniles, 64 to 90 millimeters in standard length. One of the latter had eaten a fish and the rest crustacea (one a stomatopod and another a xanthid crab chela). Four adults contained fish, crabs, and unidentified crustacean remains.

Lutjanus rivulatus
(Tahitian name: *haputu*)

A rare and very large species; individuals which were sighted underwater (most often in passes) had an estimated length in excess of 1,000 millimeters. This snapper is deep-bodied with broad yellow margins posteriorly on the median fins. The young have a black and white spot on the side. Only two juveniles were collected.

Lutjanus bohar
(Tahitian name: *haamea*)

Surprisingly rare in Tahiti, this large red species is common in the Tuamotus. It is found in passes and outer reef areas. None were obtained for food-habit study.

Lethrinus miniatus
(Tahitian name: *oeo* or *oeo uturoa*—
the young: *aaravi*)

This long-snouted species is not abundant in the Society Islands. A few specimens were collected, and one contained fish remains.

Lethrinus variegatus
(Tahitian name: *oeo* or *oeo tiamu*)

Only one specimen was obtained, and this from the Papeete market. The identification of this specimen as *L. variegatus* is uncertain.

Gnathodentex aureolineatus
(Tahitian name: *maene*)

A common fish, but not a likely introduction to Hawaiian waters because of its small size.

Plectorhynchus orientalis
(no Tahitian name)

A rare, solitary lagoon fish, this black and white species swims in peculiar sinuous fashion. Although the color pattern is similar to that described for *orientalis*, some other characteristics such as XII, 19 dorsal rays are not, and the identification of the few Tahitian specimens as this species is not without considerable doubt.

Pterocaesio tile
(no Tahitian name)

Not common in Tahiti, this slender lutjanid appears to be a plankton feeder. The stomach of one juvenile contained only plankton, primarily copepods. The gill rakers are long and slender, and the fish are consistently seen schooling in open water well off the bottom, the young usually in bays over heads of coral and the adults outside the barrier reef at depths of about 60-70 feet.

No fishes of the genus *Caesio* were seen in the Society Islands.

LITERATURE CITED

Gosline, W. A. 1955. The inshore fish fauna of Johnson Island, a Central Pacific atoll. Pacific Sci., 9 (4): 442-480.

Longley, W. H., and S. F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, Florida. Papers Tortugas Lab., 34, (Carnegie Inst. Washington, Publ. 535), xiii + 331 pp.

Randall, J. E. 1955. Fishes of the Gilbert Islands, Atoll Res. Bull. 47, xi + 243 pp.

———. 1958. A review of ciguatera, tropical fish poisoning, with a tentative explanation of its cause. Bull. Mar. Sci. Gulf and Carib., 8 (3): 236-267.

———. In press. New fishes for Hawaii. Sea Frontiers.

Schultz, L. P., E. S. Herald, E. A. Lachner, A. D. Welander, and L. P. Woods. 1953. Fishes of the Marshall and Marianas Islands. Bull. U. S. Natl. Mus. 202, xxxii + 685 pp.

Wheeler, J. F. G. and F. D. Ommanney. 1953. Report on the Mauritius-Seychelles Fisheries Survey 1948-1949. Colonial Office Fishery Publ., 1 (3), 145 pp.

Avoidance Reactions of Salmonid and Centrarchid Fishes to Low Oxygen Concentrations[1, 2]

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ABSTRACT

All of four fish species used in 174 laboratory experiments with a "channeled avoidance tank" avoided some low oxygen concentrations, the degree of avoidance generally decreasing with increasing concentration. Avoidance indices computed were based on numbers of entries into two experimental channels with reduced oxygen concentrations and two control channels, on numbers of crossings of a transverse line located well inside each channel, and on numbers of fish observed in the channels at 60-second intervals. Juvenile chinook salmon showed marked avoidance of oxygen concentrations near 1.5, 3.0, and 4.5 mg./l. in summer at high temperatures. A decrease of the avoidance observed in the fall is ascribable to lower temperatures. The chinook salmon showed little avoidance of concentrations near 4.5 mg./l. in the fall, and no avoidance of concentrations near 6.0 mg./l. at any time. At summer temperatures juvenile coho salmon showed some avoidance of all the above oxygen concentrations, including 6 mg./l., but their behavior was erratic and their avoidance of concentrations near 4.5 mg./l. and less was not as pronounced as that of chinook salmon at corresponding temperatures. Largemouth bass and bluegill markedly avoided concentrations near 1.5 mg./l., but showed little or no avoidance of the higher concentrations, only the bass showing any avoidance of concentrations near 4.5 mg./l. The nature and significance of the observed avoidance reactions are not quite clear. The prompt avoidance by some fish of oxygen concentrations well above those known to be lethal cannot be ascribed entirely to mere stimulation or increase of activity due to oxygen deficiency. It may not be assumed, however, that oxygen concentrations avoided under the experimental conditions are usually avoided likewise under natural conditions.

INTRODUCTION

Dissolved-oxygen deficiency which can be lethal to fish results frequently from pollution of inland waters with domestic and industrial wastes containing putrescible organic matter, and it can be due also to natural causes. Detection and avoidance by fish of low oxygen concentrations before these result in fish mortality obviously can be beneficial, but fish sometimes may be repelled from waters which are not otherwise unsuitable for them.

Shelford and Allee (1913) and J. R. E. Jones (1952) have demonstrated the ability of some fishes to avoid low dissolved-oxygen concentrations under certain experimental conditions (in a gradient tank and a glass tube, respectively). However, these authors' interpretations of their observations differ somewhat, and much remains to be learned about the nature of the reactions which result in avoidance, and the extent to which different oxygen concentrations are avoided by various fish species under both laboratory and natural conditions. Jones (1952) found that at a low temperature (3° C.) reaction time was much longer than in comparable tests at higher temperatures (13 to 20° C.), or no reaction at all was observed to an oxygen concentration which was soon repellent at the higher temperatures. The reaction time increased with increasing concentration. Avoidance reactions of sticklebacks, minnows, and trout to concentrations as high as 3.2 to 5.5 mg./l., at temperatures of 13 to 24° C., were reported, but the evidence presented is incomplete, and the degree of avoidance of each concentration tested was not reported quantitatively.

Results of experiments designed for determination of the degrees of avoidance of four selected concentrations of dissolved oxygen by juvenile chinook salmon, coho salmon, largemouth bass, and bluegill in a "channeled avoidance tank" are reported in this paper. This study is part of a comprehensive investi-

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gation of the effects of reduced oxygen concentrations on the survival, development, growth, activity potential, and movements of fishes, which is being pursued cooperatively by Oregon State College and the U. S. Public Health Service.

MATERIALS AND METHODS

The chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), and coho salmon, *Oncorhynchus kisutch* (Walbaum), used in these experiments were hatchery-reared fish varying in total length from 63 to 110 millimeters. The largemouth bass, *Micropterus salmoides* (Lacépède), and the bluegill, *Lepomis macrochirus* Rafinesque, were wild fish and were mostly 50 to 90 millimeters in total length. The fish were held in 250-gallon wooden tanks for at least 2 days before their use in experiments. In a few experiments only, the fish were used a second time, not less than a week after their initial use. Water pumped from Marys River was supplied to the holding tanks and the experimental apparatus.

The experimental apparatus (Figure 1) was a modification of the "channeled avoidance tank" employed by B. F. Jones *et al.* (1956) in a study of the reactions of juvenile salmon to pulp-mill wastes. It consisted, in part, of a rectangular wooden tank 112 inches long, 24 inches wide, and 12 inches deep inside, partitioned at one end into four parallel, 36-inch long channels of equal width, designated sequentially A, B, C, and D. The tank and partitions were painted white. The tank was filled with water to a depth of about 4½ inches. Each channel received water continuously from an inlet tube at the closed end. Two of the channels, A and C, or B and D, contained aerated water and served as control channels. The other two served as experimental channels, containing water of re-

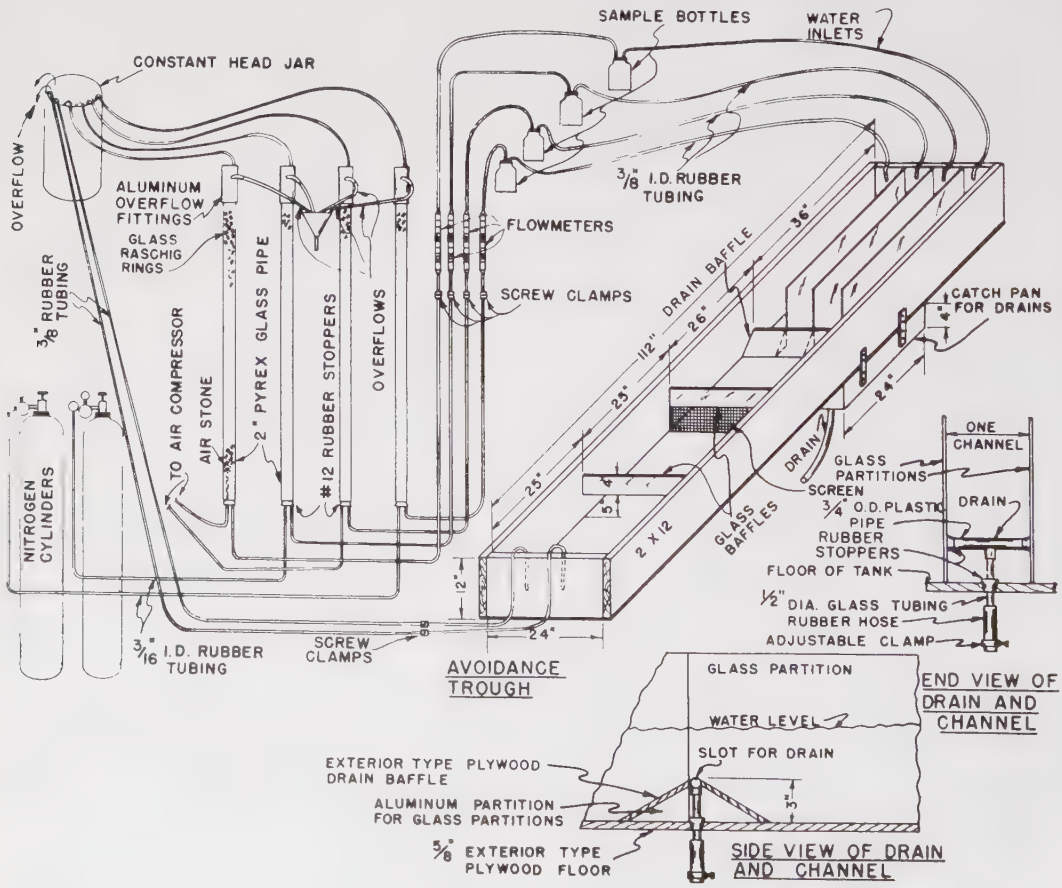

FIGURE 1.—Diagram of apparatus used for the study of avoidance reactions of fishes to low oxygen concentrations. The compartment of the laboratory room in which the avoidance trough or tank was enclosed is not shown. It has been diagrammed by B. F. Jones *et al.* (1956) in their Figure 1.

duced dissolved-oxygen content. The oxygen content was reduced by bubbling nitrogen through the water as it flowed downward through 4-foot glass columns (tubes of 2-inch inside diameter packed with Raschig rings) before its introduction into the experimental channels. Two-stage pressure-reducing valves were used for controlling the flow of nitrogen to the glass columns, which were kept full of water and overflowing at the top. The pair of channels receiving water from the two deoxygenating columns was not the same pair in successive experiments. Certain possible sources of bias thus were eliminated. Each channel had a separate, adjustable drain at the open end, slotted so as to provide drainage across the entire width of the channel at a level nearly 3 inches above the bottom of the tank. Water was prevented from passing beneath the drains and fish were guided over them by oblique baffles placed inside and outside the channels next to the drains.

The rates of flow of water into the channels and out through the drains were carefully adjusted, by means of screw clamps, to minimize mixing of the water in the channels with the water outside the channels. The flow into each channel was about 1,200 milliliters per minute. The flow from each of two additional inlets located at the end of the tank opposite the channeled end was adjusted to approximate 600 milliliters per minute. The flow from each drain was about 1,500 milliliters per minute, so that the total outflow through the four drains equalled the total inflow from the six inlets. A transverse screen of wire netting placed in the main body of the tank 26 inches from the open ends of the channels and supported by a glass baffle confined the test fish to a 62-inch long portion of the tank including the channels. The tank was enclosed in a separate compartment of the laboratory room to minimize disturbance of the fish. The fish were observed through a polarized glass window in the wall at one end of the compartment. A 2-tube, 96-inch, fluorescent light fixture suspended from the ceiling of the white-walled compartment provided fairly uniform illumination of the tank.

Dissolved-oxygen concentrations were determined by the Alsterberg (azide) modification of the Winkler method (American Public Health Association *et al.*, 1955), using 50-milliliter water samples. The samples were taken at points inside each channel 3 inches and 12 inches from the entrance, and outside each channel 3 inches from the entrance. These points were equidistant from the channel walls and at a depth of about 1 inch. Dissolved-oxygen determinations were made just before and after each 45-minute experiment. Sample bottles connected to the input water lines facilitated adjustment of oxygen concentrations to the desired levels. The concentrations at the two sampling points inside each channel were found to differ very little.

Excepting control experiments wherein oxygen concentrations were uniform throughout the tank, dissolved-oxygen concentrations maintained in the two experimental channels were near 1.5, 3, 4.5, or 6 mg./l. The control channels received water which had been aerated in 4-foot glass columns. The main body of the tank received water which had not been aerated and also a small admixture of modified water unavoidably diffusing out of the channels. The dissolved-oxygen concentrations in the middle of that portion of the body of the tank into which the fish were introduced were not determined regularly. When determined, they were found to be equal to, or slightly higher than, the means of the concentrations found at the same time at the four sampling points just outside the experimental and control channels, 3 inches from the channel entrances. In control experiments the flow of nitrogen and of air to the glass columns was discontinued, so that all of the water flowing into the tank (including the four channels) was unaerated river water. Inasmuch as no avoidance of 6 mg./l. dissolved oxygen was shown by most of the fish species tested, experiments with this oxygen concentration in the experimental channels often served as adequate substitutes for additional control tests.

The tests were performed at variable river water temperatures, no provision having been made for temperature regulation. Ten to thirty-five fish were used simultaneously in each experiment. The most satisfactory number depended upon the activity of the fish. When water temperatures were above 21° C., the salmon were not very active, and relatively large numbers of these fish were necessary for obtaining a sufficient number of entries into the channels. Recorded observations were started only after the fish began to move freely about the tank, 3 to 30 minutes (usually about 10 minutes) after the introduction of the fish, and were continued for 45 minutes.

Two markers were used in recording different degrees of penetration of each channel by the fish. The first marker was the drain at the channel entrance. The second marker was a piece of black rubber tubing fixed to the bottom of the tank inside each channel, 24 inches from the entrance. These markers will be referred to as the first and second lines, respectively. A crossing of a line was recorded only when it seemed to the observer that the caudal fin of a fish had passed a marker completely. Each entry into a channel (crossing of the first line) was recorded, but only the first crossing of the second line after every such entry was recorded. Also the number of fish present in each channel was recorded at 60-second intervals throughout each experiment.

The measures of avoidance of experimental channels used in this study are referred to as "avoidance indices." Each avoidance index is based on one of the three different kinds of observations mentioned above, and has been computed by the formula:

$$\text{Avoidance index} = 100(M—A)/M$$

where M is the sum of the observations for all channels (experimental and control) divided by 2, and A is the sum of the observations for the experimental channels only.

A positive avoidance index based on numbers of entries into the channels during a single experiment shows that the number of entries into the experimental channels was less than the number of entries into the control channels. A negative index shows that the number of entries into the experimental channels exceeded the number of entries into control channels. A positive index of 20 would show that the entries into the control channels were 1.5 times as frequent as entries into the experimental channels; and indices of 33, 50, 67, 80, and 90 would mean that the former entries were 2, 3, 5, 9, and 19 times as frequent as the latter entries, respectively. It must be emphasized, however, that the above relationships will not hold exactly for the mean avoidance indices (based on groups of similar but independent experiments) which are reported in this paper. It should be noted also that the avoidance index computed by the formula given cannot exceed 100, this value signifying complete avoidance, or no entries at all into the experimental channels, nor can the index be less than —100[6].

RESULTS

The chinook salmon, coho salmon, largemouth bass, and bluegill used in the experiments all avoided water when the level of dissolved oxygen was sufficiently low. The mean avoidance indices for different oxygen concentrations, obtained in series of similar tests with each of the four species of fish, are given in Table 1. Standard errors of the mean avoidance indices are also given. Results of tests performed at different seasons of the year, as well as tests with widely different oxygen concentrations in the experimental channels, are considered separately. Table 2 shows, for each set of similar experiments considered together, the mean dissolved-oxygen concentrations inside the experimental and control channels and outside these channels at a distance of 3 inches from the drains, and also the water temperatures (mean and range). Mean avoidance indices obtained in tests with chinook salmon at different temperatures in the summer, and also in the fall, with oxygen concentrations of about 1.5 and 3 mg./l. in the experimental channels, are presented for comparative purposes in Table 3. The actual observations made and the avoidance indices obtained in most of the individual experiments, and also the dissolved-oxygen concentrations and water temperatures on which are based the means and ranges recorded in the tables, have been reported by Whitemore (1957).

[6]Jones *et al.* (1956), in their study of the avoidance reactions of salmon to pulp-mill effluents, used a different formula for the computation of "per cent avoidance." Their formula was based on the assumption that avoidance of experimental channels had little influence on the numbers of entries into the control channels. This assumption may not be entirely valid. Although it cannot be assumed that a fish which has been repelled from an experimental channel immediately enters a control channel instead, there is good evidence that this does not usually occur. The original formula of Jones *et al.* (1956) was not deemed satisfactory for use in the present study because it is capable of yielding unlimited negative values (to infinity), while yielding positive values not greater than 100. No extreme negative "per cent avoidance" was obtained in any test in the course of the earlier investigation, so that the original formula's "negative bias" was not serious. In the present, more extensive study, application of the original formula yielded rather extreme negative values on several occasions, and a different formula consequently had to be devised.

TABLE 1.—*Avoidance of various dissolved-oxygen concentrations by chinook salmon, coho salmon, largemouth bass, and bluegill*

Species	Months and year	Mean dissolved oxygen in experimental channels (mg./l.)	Number of experiments	Mean avoidance indices					
				First line		Second line		Periodic count	
				Mean	Standard error	Mean	Standard error	Mean	Standard error
Chinook salmon	June, July 1956	1.6	8	61.0	3.8	90.1	3.8	89.5	2.9
		3.0	8	46.7	8.2	67.6	10.5	71.9	5.5
		4.5	4	27.6	1.5	38.4	2.4	35.3	6.4
		6.1	7	−1.9	10.6	−4.7	12.9	−1.9	14.7
	October, November, 1956[1]	1.6	8	27.8	2.9	72.1	7.3	67.4	4.8
		3.0	8	19.8	2.6	39.8	6.3	43.3	4.4
		4.5	8	3.4	5.0	5.4	6.2	8.0	7.1
		6.0	9	0.0	8.1	−5.1	8.3	−8.3	9.4
		9.6[2]	8	3.0	4.7	12.3	6.7	5.2	6.8
	December, 1957	3.0	6	16.0	8.5	42.5	19.7	45.9	20.7
Coho salmon	July, 1956	1.6	4	25.2	10.5	53.2	8.5	56.6	18.0
		3.1	5	18.3	5.7	26.9	8.2	37.6	7.8
		4.6	4	12.0	5.8	20.4	9.0	21.3	11.6
		5.9	5	8.1	7.7	18.0	5.0	35.0	12.0
	October, 1956	6.8[2]	3	−2.5	13.4	3.1	19.0	2.7	18.9
Largemouth bass	August, September, 1956	1.5	8	23.6	7.7	48.8	6.5	69.5	3.4
		3.0	12	6.8	5.1	9.4	5.4	11.1	5.8
		4.6	13	5.0	3.8	9.7	4.9	10.2	4.4
		6.1	8	−0.9	7.0	−2.6	6.0	2.2	6.7
		7.9[2]	10	3.2	3.1	5.2	3.6	7.0	6.4
Bluegill	August, September, 1956	1.5	8	18.4	7.1	51.8	7.8	60.5	6.2
		3.1	6	−0.5	8.3	9.8	12.0	28.9	11.3
		4.6	6	2.8	7.5	2.5	9.3	−2.7	11.9
		6.0	5	4.3	4.8	−0.1	11.3	−5.4	7.8
		8.2[2]	3	6.2	6.0	6.9	15.6	14.7	25.7

[1]Two experiments performed on September 29, 1956, are included.
[2]Control experiments with nearly the same dissolved-oxygen concentration in the control channels.

No complete avoidance of any oxygen concentration by any of the fish species (Table 1) has been observed, and, therefore, the mean avoidance index was never 100. No influence of variation in size and age of the experimental animals on their avoidance of low oxygen concentrations could be detected.

Chinook salmon

The chinook salmon showed some avoidance of water with dissolved-oxygen concentrations near 1.5, 3, and 4.5 mg./l., but not with 6 mg./l. In all cases the mean avoidance indices became progressively larger with progressive reduction of the oxygen concentration below 6 mg./l. The chinook salmon reacted markedly to low concentrations. They often turned sharply away from the entrances to the experimental channels. Fish which entered the experimental channels often turned and retreated promptly, and usually reacted without evident confusion or distress. The avoidance indices pertaining to crossings of the second line and those based on periodic counts of fish in the channels consequently are even greater than corresponding indices pertaining to crossings of the first line (*i.e.*, entries into channels).

Considerable seasonal differences in degrees of avoidance are shown by the results of tests performed with two groups of chinook salmon at different times in 1956. In the fall the fish showed much less avoidance of oxygen concentrations below 6 mg./l. than in June and July (Table 1) although the behavior was not otherwise strikingly different. Chinook salmon avoided water with 4.5 mg./l. dissolved-oxygen content rather markedly in the summer experiments, but they showed little avoidance of approximately the same mean oxygen concentration in the fall. Six experiments performed during December 1957 showed avoidance of 3 mg./l. dissolved oxygen differing little from that observed in the fall of 1956.

The seasonal differences of avoidance are explained in large part by seasonal differences of water temperature. Data presented in Table 3 show that, for the same low oxygen concentrations which were markedly avoided, the

mean avoidance indices were greater when water temperatures were high than when the temperatures were lower. Temperature influenced avoidance in tests performed at different temperatures during the same season as well as in different seasons.

Chinook salmon and other test species entered the two outer channels (A and D) of the experimental tank more often than they entered the two inner channels (B and C). In eight control experiments with chinook salmon performed in November 1956, the outer channels were entered 2,466 times and the inner channels only 1,064 times. In eight experiments on avoidance of the 1.5 mg./l. dissolved-oxygen level performed during June and July 1956, the fish entered the outer control channel 2,026 times, whereas they entered the inner control channel only 222 times. Somewhat higher avoidance indices have been obtained by using the data for the two outer channels only than by using those for all the channels. When the June and July figures for channels A and D only were used, the resulting mean avoidance indices pertaining to crossings of the first line, to crossings of the second line, and to periodic counts of fish in the channels were, respectively, 76.0, 94.8, and 93.0 for oxygen concentrations near 1.5 mg./l.; 55.9, 69.2, and 77.6 for concentrations near 3 mg./l.; and 39.3, 45.9, and 46.5 for concentrations near 4.5 mg./l. It will be noted that the above values are all greater than the corresponding values (Table 1) which are based on data for all the channels. The differences between the comparable indices probably are referable, at least partly, to schooling behavior of the young chinook salmon. The entrance of a channel sometimes appeared to be too narrow to admit readily an entire school of fish exploring the experimental tank together. When the leader of a school entered the outer control channel (which was visited most frequently), some other individuals apparently were separated frequently from the rest of the school by the partition between the control channel and the adjacent (inner) experimental channel. This splitting of a school often appeared to result in the entry into the

TABLE 2.—*Experimental conditions under which chinook salmon, coho salmon, largemouth bass, and bluegill of Table 1 were tested for avoidance reactions*

Species	Months and year	Dissolved-oxygen concentration (mg./l.)					Temperature (degrees C.)	
		Inside experimental channels		Inside control channels	Outside experimental channels[2]	Outside control channels[2]		
		Mean	Range[1]	Mean	Mean	Mean	Mean	Range
Chinook salmon	June, July, 1956	1.6	1.4-2.0	8.9	6.0	7.1	20.7	16.5-25.5
		3.0	2.9-3.0	9.2	6.2	7.4	20.8	16.5-25.5
		4.5	4.5 only	8.8	6.7	7.6	22.8	21.5-24.5
		6.1	5.7-6.3	9.4	7.4	8.1	18.4	16-21.5
	October, November, 1956[3]	1.6	1.5-1.9	10.5	7.2	7.6	13.1	8.5-18
		3.0	2.8-3.1	10.7	7.9	8.1	13.2	10.5-16.5
		4.5	4.5-4.6	11.2	8.7	8.7	12.3	9-17
		6.0	5.6-6.3	10.5	7.8	8.0	11.8	9-14
		9.6	8.8-10.0	9.7	9.7	9.7	8.1	6.5-10
	December, 1957	3.0	2.9-3.4	10.3	9.4	9.7	8.0	8 only
Coho salmon	July, 1956	1.6	1.5-1.7	9.3	6.4	7.4	19.0	18-21
		3.1	3.0-3.3	9.3	7.0	8.0	18.5	17-20.5
		4.6	4.5-4.6	9.2	7.1	8.0	19.0	18.5-20.5
		5.9	5.6-6.2	9.4	7.7	7.9	18.4	17-20.5
	October, 1956	6.8	6.8-6.9	6.8	6.8	6.8	13.5	13.5 only
Largemouth bass	August, September, 1956	1.5	1.4-1.6	8.9	5.8	7.3	20.0	17.5-22
		3.0	2.9-3.1	9.2	6.4	7.6	19.9	17.5-21.5
		4.6	4.3-4.8	9.3	7.2	7.9	19.5	17.5-22.5
		6.1	5.9-6.4	9.7	7.7	8.2	18.7	17-20
		7.9	7.4-8.5	7.8	7.8	7.8	18.8	17-20
Bluegill	August, September, 1956	1.5	1.4-1.6	8.9	5.8	7.0	21.0	19.5-24
		3.1	3.0-3.4	9.0	5.9	7.1	19.8	18.5-20.5
		4.6	4.5-4.7	9.8	7.4	8.6	18.5	17-19.5
		6.0	5.9-6.1	9.5	7.7	8.1	19.5	17-21.5
		8.2	7.9-8.3	8.2	8.2	8.2	20.0	19-21

[1]Range of means of eight determinations on samples taken at two points inside each experimental channel at the beginning and end of each experiment.
[2]Three inches from the entrances of the two channels.
[3]Two experiments performed on September 29, 1956, are included.

inner experimental channel of some fish which would have entered the outer control channel if there had been no congestion at the entrance.

The schooling of chinook salmon may have influenced their avoidance of low oxygen concentrations in another manner and perhaps increased the magnitude of the avoidance. The hesitation of the leader of a school at the entrance of an experimental channel or the sudden turning of the leader after entry into the channel often seemed to change the direction of movement of other fish which were following but had not yet entered the channel. If all the fish had been exploring the tank independently, more might have entered the experimental channels. Schooling of chinook salmon was noted principally in summer experiments.

Coho salmon

The coho salmon tested in July avoided dissolved-oxygen concentrations near 1.5, 3, 4.5, and 6 mg./l. to some extent in nearly all experiments. When the concentrations were near 1.5 mg./l., the avoidance indices based on crossings of the second line and on periodic counts of fish in the channels averaged more than 50 (Table 1). The corresponding mean avoidance index based on entries into the channels is only 25.2. The first line avoidance index declines rather uniformly with each increase of the experimental oxygen concentration within the range of 1.5 to 6 mg./l. The indices based on crossings of the second line and on periodic counts, on the other hand, declined rather sharply with increase of oxygen concentration from about 1.5 to about 3 mg./l., and declined relatively little with further increase of the concentration up to 6 mg./l. Because there was a shortage of experimental material, no control experiments with coho salmon were performed in July. The few control tests made were undertaken much later in the year (October) when water temperatures were relatively low.

The movements of the coho salmon in the avoidance tank were rapid and somewhat erratic. They often started upon entering water of low oxygen content, then darted about the experimental channel until they found their way out. No schooling of coho salmon was observed during the experiments.

Largemouth bass

Marked avoidance of 1.5 mg./l. dissolved oxygen only was observed in experiments with largemouth bass. It was obvious that, having entered the channels, the bass usually left the low oxygen channels much sooner than they left the control channels. The mean avoidance index (69.5) based on periodic counts of fish in the channels, therefore, was much greater than that based on first-line crossings (23.6), and the index based on second-line crossings (48.8) fell between these values. When the tested oxygen concentration was increased to about 3 mg./l. or more, the mean avoidance indices declined sharply to values less than 12, but some avoidance of concentrations near 4.5 mg./l. was indicated. No avoidance of 6 mg./l. dissolved oxygen was detected. Schooling behavior was noted only in two experiments in which very young bass were used.

Bluegill

Bluegill avoided oxygen concentrations near 1.5 and 3 mg./l. The highest mean avoidance indices obtained were those based on periodic counts of fish in the channels. The avoidance of 3 mg./l. dissolved oxygen was not very pronounced and was shown principally by the counts of fish in the channels. These counts showed that the fish did not remain as long in the experimental as in the control channels, inasmuch as the numbers of entries into both were almost equal. No avoidance of 4.5 and 6 mg./l. dissolved oxygen was apparent. Some of the bluegill defended their positions in the tank, thereby presumably influencing the movements of other individuals in some of the experiments. Schooling was not observed.

DISCUSSION

Each of the four species of fish avoided markedly the lowest tested concentration of dissolved oxygen (1.5 mg./l.), and, except bluegill, all (especially the salmon) showed some avoidance of oxygen concentrations as high or higher than 4.5 mg./l. The species differed not only in the magnitude of their avoidance of low oxygen concentrations in comparable tests, but also in the manner of their reaction. Coho salmon apparently responded to higher oxygen concentrations, or to smaller differences of concentration, than

the chinook salmon, but their avoidance of relatively low concentrations was less definite or pronounced than that of the chinook salmon. The responses of the coho salmon were somewhat erratic at the low levels. Only the coho salmon showed some avoidance of 6 mg./l. dissolved oxygen. In experiments performed in summer, the avoidance of each tested concentration below 6 mg./l. shown by chinook salmon was greater than that shown by coho salmon at about the same time of year. The mean temperatures of the summer experiments with chinook were somewhat higher than those of the experiments with coho, and it has been shown that the avoidance of low oxygen concentrations by chinook salmon decreases with falling temperature (Table 3). Comparison, however, can be made of data on the avoidance of both 1.5 mg./l. and 3 mg./l. dissolved oxygen by chinook salmon at temperatures of 16.5 to 18.5° C. in the summer (Table 3) and at 15.5 to 18° C. early in the fall (Table 3) with the data obtained with coho salmon in summer at temperatures of 18.4 to 19° C. (Table 1). The avoidance of these low concentrations by the chinook salmon even at relatively low temperatures (15.5 to 18.5°) was decidedly greater than that of the coho salmon at temperatures of 18.4 to 19° C. Largemouth bass apparently responded to concentrations as high as 4.5 mg./l., but did not avoid markedly any tested concentration above 1.5 mg./l. Comparison of the reactions of the salmonids and the centrarchids must be made without forgetting that experimental temperatures near 20° C. are much closer to the upper limits of thermal tolerance of the salmonids than of the centrarchids.

Avoidance by fish of water with low dissolved-oxygen concentration was shown not only by shorter excursions (in both distance and time) into the experimental channels than into control channels, but also by fewer entries into the low oxygen channels than into control channels. Avoidance at the first line suggests an almost instantaneous response (change in direction of movement) to a change of oxygen concentration detected rapidly by the fish at a channel's entrance. It is recognized, however, that learning to avoid channels with unfavorable oxygen concentrations, and interaction among individuals traveling together may be involved to an extent not yet determined. Avoidance revealed by the second-line observations only is interpreted as a somewhat delayed response to a change of oxygen concentration which may or may not have been detected at the first line. Avoidance revealed by periodic counts of fish in the channels can be a result of gradually produced discomfort and stimulation at reduced oxygen concentrations.

Shelford and Allee (1913) found that fish of some species tended to avoid water with a low oxygen content in a gradient tank by turning back to water with a more favorable oxygen concentration. J. R. E. Jones (1952) also noted that fish are able to retreat promptly from water with low oxygen levels. Although he observed such behavior repeatedly in testing low concentrations at relatively high temperatures, on the basis of his studies of the stickleback, *Gasterosteus aculeatus*, the minnow, *Phoxinus phoxinus*, and brown trout fry, *Salmo trutta*, he concluded

> "that fish do not have any instinctive ability to recognize immediately and avoid water of abnormally low oxygen content, that they swim into it with little or no hesitation when the oxygen concentration and temperature do not provoke immediate and acute respiratory distress, and if they eventually avoid it

TABLE 3.—*Avoidance of low dissolved-oxygen concentrations by chinook salmon in different seasons in relation to temperature—1956 experiments*

Season	Mean dissolved oxygen in experimental channels (mg./l.)	Temperature (degrees C.)		Number of experiments	Mean avoidance indices		
		Range	Mean		First line	Second line	Periodic count
Summer	1.6	16.5-18.5	17.1	4	59.4	84.4	84.0
	1.6	22.5-25.5	24.2	4	62.7	95.9	95.0
	3.0	16.5-19	17.6	4	39.0	53.1	60.9
	3.0	22-25.5	23.9	4	54.4	82.2	83.0
Fall	1.6	8.5-10	9.2	4	27.3	59.3	60.3
	1.6	15.5-18	17.0	4	28.3	84.8	74.0
	2.9	10.5-11.5	11.2	4	16.9	29.0	36.2
	3.1	13.5 only	13.5	1	10.3	26.0	30.1
	3.0	15.5-16.5	15.8	3	29.4	58.8	57.1

> the basis of the reaction would appear to be the active, random swimming and struggling that appears to be incited by dyspnoea."

Jones further suggested that more rapid movement may be a natural response to oxygen deficiency. In considering the reactions of the stickleback he concludes that the basis of its selection of well-oxygenated water appears to be the sudden removal of the stimulus to swimming when the fish returns to such water through random movement. The results of experiments reported herein cannot all be explained in the same manner.

Chinook salmon showed pronounced avoidance of moderately low oxygen concentrations at the first line, or, if they entered the channels, often turned back sharply soon after entry without having shown any visible signs of acute respiratory distress. While the reactions of other tested species to the same concentrations were usually somewhat less pronounced and definite, or more erratic, the avoidance of low concentrations by these fish at the entrances of the channels cannot be disregarded. It suggests very rapid detection of the changes of water quality. Furthermore, data on crossings of the second line by coho salmon, and the periodic counts of these fish in the channels, indicate considerable avoidance of oxygen concentrations near 6 mg./l. These levels could not cause serious respiratory difficulties and were not far below the concentrations (near 8 mg./l.) in the main body of the experimental tank to which the fish had been accustomed. The large differences between first-line and second-line avoidance indices frequently obtained with all test species clearly indicate prompt directional changes of movement of fish which had entered channels with oxygen-deficient water. Mere acceleration of movement could not have resulted in such differences.

The experimental tank in which the avoidance reactions have been studied was not designed as a model of a natural situation. In the experimental apparatus the transition from high to low oxygen concentration is abrupt and occurs within a distance of a few inches. In nature the transition usually is much more gradual, and the extent of the transition zone may be a number of miles. Poorly oxygenated water, however, can occur in close proximity to well oxygenated water at the confluence of a polluted and a relatively unpolluted stream, or at the outfall of a sewer. A steep vertical gradient of oxygen concentration can be associated with density stratification, *e.g.*, in a thermally stratified lake. It is probable that an abrupt change of water quality encountered by a moving fish is more readily detected and can be more strongly repellent than a gradual change of the same magnitude. It may be assumed, therefore, that fish in the experimental tank will detect and show some response to a difference of water quality that is repellent in nature. It cannot be assumed, however, that fish in nature usually avoid reduced oxygen concentrations which they avoided in the experimental tank.

Under natural conditions reduced dissolved-oxygen concentrations are associated with elevated carbon-dioxide tensions. It has been reported that fish react strongly to very small differences of carbon-dioxide tension and avoid elevated tensions (Powers and Clark, 1943; Collins, 1952). It might be assumed that water with reduced oxygen content in nature, if avoided by fishes, may be avoided largely because there is an increased carbon-dioxide tension. In experiments reported herein carbon-dioxide tensions were not increased but were probably reduced by bubbling nitrogen through the water. The reactions of fishes reported here are believed to be in response only to reduced dissolved-oxygen concentration. Variations of the free carbon-dioxide content of the water used in the experiments may have influenced results of reported tests, because the sensitivity of fishes to oxygen deficiency may increase with increases in carbon-dioxide concentration.

The present study has demonstrated avoidance by juvenile chinook and coho salmon at temperatures near and below 20° C. of dissolved-oxygen concentrations well above those concentrations (near 2 mg./l. and less) which have been reported to be lethal for some of these fish within 24 hours at 20° C. (Katz, Pritchard, and Warren, 1959; Davison *et al.*, 1959). Largemouth bass also avoided concentrations which they doubtless could have tolerated for long periods at the test temperatures. Preliminary experiments with bass averaging 76 millimeters in length, performed in Corvallis in 1957, have indicated that concentrations lethal for these fish within 24 hours at temperatures near 20° C. are below 1 mg./l.

It is unlikely, however, that the avoidance reactions of fishes to low oxygen concentrations have no relation to the minimum dis-

solved-oxygen requirements of the fishes and to conditions prevailing in their natural habitats. Increased susceptibility of fishes to oxygen deficiency at high temperatures has been demonstrated by experiments with coho salmon (Davison *et al.*, 1959), trout and smallmouth bass (Burdick *et al.*, 1954), and other forms. The reduced avoidance of low oxygen levels shown by chinook salmon at lower temperatures was therefore to be expected. It might also have been expected that the two centrarchids tested would appear to be somewhat less responsive than the salmonids to moderately low oxygen concentrations at the experimental temperatures. Young salmon ordinarily inhabit cool, well aerated stream waters, whereas largemouth bass and bluegill are commonly found in ponds, lakes, and sluggish streams where high temperatures and large fluctuations of dissolved oxygen are not unusual.

LITERATURE CITED

American Public Health Association *et al.* 1955. Standard methods for the examination of water, sewage, and industrial wastes. Tenth edition. Amer. Public Health Assoc., New York. 522 pp.

Burdick, G. E., M. Lipschuetz, H. F. Dean, and E. F. Harris. 1954. Lethal oxygen concentrations for trout and smallmouth bass. New York Fish and Game Jour., 1: 84-97.

Collins, G. B. 1952. Factors influencing the orientation of migrating anadromous fishes. Fish. Bull., U. S. Fish and Wildl. Serv., 52: 375-396.

Davison, R. C., W. P. Breese, C. E. Warren, and P. Doudoroff. 1959. Experiments on the dissolved oxygen requirements of cold-water fishes. Sewage and Ind. Wastes, 31: 950-966.

Jones, B. F., C. E. Warren, C. E. Bond, and P. Doudoroff. 1956. Avoidance reactions of salmonid fishes to pulp-mill effluents. Sewage and Ind. Wastes, 28: 1403-1413.

Jones, J. R. E. 1952. The reactions of fish to water of low oxygen concentration. Jour. Exp. Biol., 29: 403-415.

Katz, M., A. Pritchard, and C. E. Warren. 1959. The ability of some salmonids and a centrarchid to swim in water of reduced oxygen content. Trans. Am. Fish. Soc., 88: 88-95.

Powers, E. B., and R. T. Clark. 1943. Further evidence of chemical factors affecting the migratory movements of fishes, especially the salmon. Ecology, 24: 109-113.

Shelford, V. E., and W. C. Allee. 1913. The reactions of fishes to gradients of dissolved atmospheric gases. Jour. Exp. Zool., 14: 207-266.

Whitmore, C. M. 1957. Avoidance reactions of some salmonid and centrarchid fishes to low concentrations of dissolved oxygen. M.Sc. Thesis, Oregon State College, 68 pp.

Growth of Eight Species of Fishes in Quabbin Reservoir, Massachusetts, In Relation to Age of Reservoir and Introduction of Smelt[1]

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ABSTRACT

Growth rates of eight species of fish taken by angling from Quabbin Reservoir, a 25,000-acre impoundment in Massachusetts, were determined for all or two of the following three periods of the reservoir's history: A—while the reservoir was filling; B—during the first 7 years after it had filled; and C—after the smelt had been introduced. Growth of yellow perch *(Perca flavescens)* showed little change over the three periods; that of white perch *(Morone americana)* declined. Growth of smallmouth bass *(Micropterus dolomieui)* and chain pickerel *(Esox niger)* increased somewhat after introduction of smelt but that of black crappie *(Pomoxis nigromaculatus)* and largemouth bass *(Micropterus salmoides)* remained essentially unchanged. There was a marked increase in growth rates of lake trout *(Salvelinus namaycush)* and brown trout *(Salmo trutta)* after smelt had become abundant (1954-1958). The proportion of game fishes (black basses, pickerel, and trouts) in the total angling catch increased from 2.1 to 5.4 percent by numbers and 11.0 to 23.0 percent by weight after introduction of smelt. Average angling yield in this deep, soft-water reservoir is 2.5 pounds per acre per year.

INTRODUCTION

Quabbin Reservoir, a 25,000-acre impoundment which is the main water supply for metropolitan Boston, was created by the completion of a dam on the Swift River in 1939. By 1946 the pool had reached spillway level, giving a maximum depth of 150 and a mean depth of 50 feet. Prior to flooding, the bottom of Quabbin Reservoir was cleared to an elevation above the shoreline but was not stripped of the topsoil (Reed, 1947).

The oxygen content of the bottom water fell to zero, or nearly so, during the summer and fall stagnation periods the first 3 years of impoundment, but has not been below 29 percent saturation since 1942. On the average, oxygen near the bottom has ranged between 60 and 80 percent saturation, and sometimes been higher, since 1943. During the summer a thermocline usually forms at depths between 30 and 50 feet, below which temperatures range from 69°F. to 47°F. at the bottom. Usual hydrogen-ion concentration is 6.7 at the surface and 6.3 at the bottom. There has been no marked change in the average pH since the reservoir started to fill. Turbidity readings range between 0.7 and 0.8 p.p.m. and the water is soft with methyl-orange alkalinity determinations varying between 4.1 and 4.5 p.p.m.

The bottom is largely rubble, except in a few weedy coves where muck predominates. Water-level fluctuations are not great (usually less than 5 feet) and generally occur in the late summer, if at all.

All fishing was prohibited until the reservoir was full in 1946 when shore fishing was permitted along 46 miles of the reservoir's 118 miles of shoreline. Prior to 1946 all roads leading into the reservoir grounds were barricaded against ingress by cars, and even after opening of 46 miles of shore fishing, much of it was not fished because of the great distance from the gates to the shoreline. Boat fishing was first permitted in 1952 when three state-controlled boat liveries were constructed, and approximately 65 percent of the surface area of the reservoir opened to angling.

Fishing pressure and angling harvest were determined by creel census during the period 1954-1958 (McCaig, in press). For the area open to fishing (16,850 acres), fishing pressure was 13.7 hours per acre per year and an angling yield per acre per year of seven fish, weighing 2.5 pounds. During these years yellow perch *(Perca flavescens)*, white perch *(Morone americana)*, and brown bullhead *(Ameiurus nebulosus)* made up 70 percent of the fish taken and 89 percent of the weight. Other panfishes in the catch were, in decreasing order of importance: bluegill *(Lepomis macrochirus)*, pumpkinseed *(Lepomis gibbosus)*, redbreast sunfish *(Lepomis auritus)*,

[1]Contribution of Dingell-Johnson Project F-6-R, Massachusetts.

black crappie *(Pomoxis nigromaculatus)*, and rock bass *(Ambloplites rupestris)*. Game fish taken were largemouth bass *(Micropterus salmoides)*, smallmouth bass *(Micropterus dolomieui)*, chain pickerel *(Esox niger)*, brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, rainbow trout *(Salmo gairdneri)*, and lake trout *(Salvelinus namaycush)*. Game fish in the catch increased from 2.1 to 5.4 percent numerically and from 11.1 to 23.0 percent by weight between 1954 and 1958. White suckers *(Catostomus commersoni)* and fallfish *(Leucosomus corporalis)* were the principal rough fish taken by anglers.

Species now present in Quabbin Reservoir but not taken by anglers include golden shiner *(Notemigonus crysoleucas)*, spottail shiner *(Notropis hudsonius)*, bridled minnow *(Notropis bifrenatus)*, killifish *(Fundulus diaphanus)*, johnny darter *(Boleosoma nigrum)*, common shiner *(Notropis cornutus)*, and smelt *(Osmerus mordax)*.

With the exception of lake trout and smelt all the species mentioned were presumably indigenous to the streams and ponds inundated by the reservoir. Lake trout and smelt populations developed from introductory stockings. Approximately 45,000 smelt were stocked in 1953 and 1954. Progeny from these stocks have established a large population, and spawning runs were first observed in the spring of 1957. Smelt were so abundant in 1958 that they clogged screens of the gravity-feed water intakes causing a loss of pressure.

AGE AND GROWTH

Methods

Annual growth increments for the species considered in this paper were computed from body-scale relationships of fish taken by hook and line. Scales were collected throughout the open fishing season (late April through October). Fish from which scales were taken were measured for total length to the nearest tenth of an inch. Age determinations and scale measurements were made with an Eberbach scale projector. The generally accepted procedures for age and growth studies by the

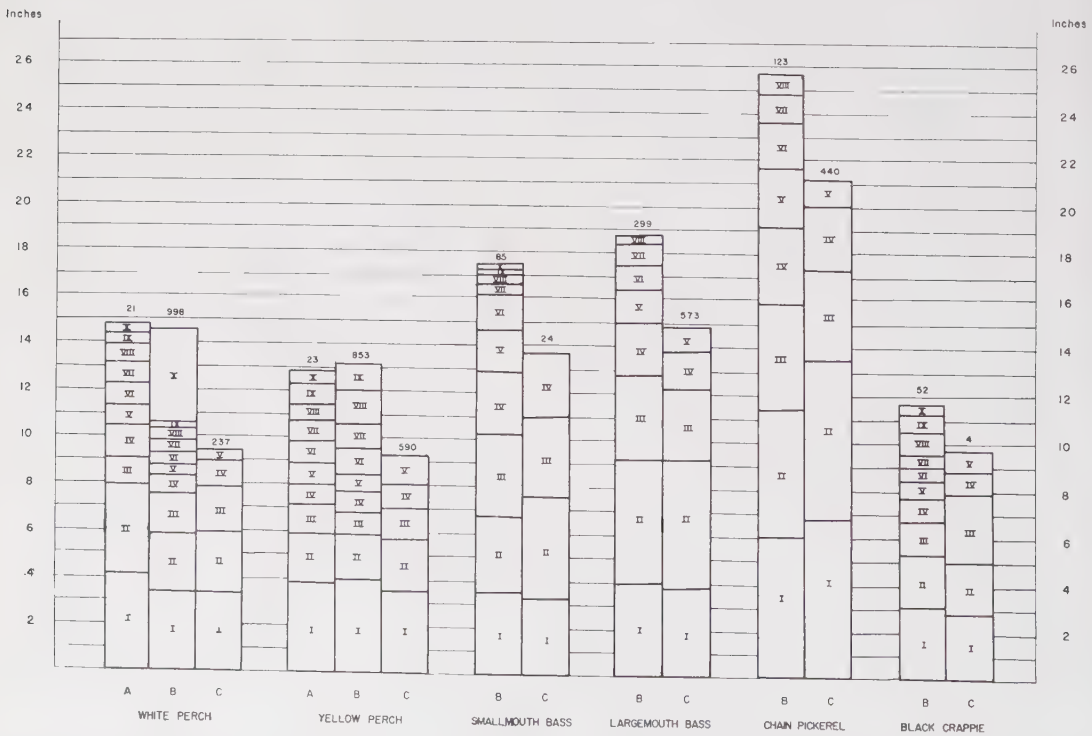

FIGURE 1.—Growth of six species of warm-water game fish in Quabbin Reservoir, Massachusetts, during three periods: A — while reservoir was filling; B — during 5 years after filling; and C — after introduction of smelt. Numbers on top of the columns are number of scale readings made; lengths are calculated total lengths at the end of the year of life indicated by the Roman numerals.

scale method were followed (Van Oosten, 1929; Hile, 1941). A direct proportion nomograph, utilizing a standard correction factor of 1.25 inches, was used for all calculations.

Growth of yellow perch

Scales were studied from 1,466 yellow perch, representing year classes dating back to 1942 when the reservoir was first filling (Figure 1, Table 1). From 16,000 to 32,000 yellow perch, averaging one-fifth of a pound in weight, were harvested annually in the period 1954-58. No significant variation in the growth increment over the entire 16-year period is discernible. Yellow perch averaged 7.7, 11.7, and 13.6 inches at 4, 8, and 12 years of age, respectively. Such a growth rate for yellow perch is intermediate with that reported by Stroud (1955) and Grice (in press) for other Massachusetts waters of smaller size.

White perch

Analysis of 1,265 white perch representing annual year classes spawned between 1942 and 1957 indicates a decline in growth rate after 1946 and a slight acceleration during the last 2 years (Figure 1, Table 1). The catch has ranged from 25,000 to 39,000 white perch annually between 1954 and 1958. In 1958 average size increased to 0.47 pound over averages of 0.31 to 0.35 pound for the previous 4 years.

White perch averaged 8.2, 11.2, and 14.8 inches at 4, 8, and 12 years of age. This growth can be considered fair to good in comparison to that reported by Stroud (1955) and Cooper (1941).

Black crappie

Only 56 black crappies were aged, representing year classes spawned between 1946 and 1954 (Figure 1, Table 1). They are included because of the marked decline in the

TABLE 1.—*Average growth rates of six species of fish in Quabbin Reservoir, Massachusetts; A—while reservoir was filling (1942-1946); B—before abundance of smelt (1946-1952); and C—after abundance of smelt (1953-1957)*

[Lengths are calculated total lengths in inches at the end of the year indicated; numbers in parentheses are the number of scale readings on which the average is based]

Species	Period	Age									
		I	II	III	IV	V	VI	VII	VIII	IX	X
White perch	A	4.1 (21)	7.9 (21)	9.0 (21)	10.4 (21)	11.3 (21)	12.2 (21)	13.1 (21)	13.9 (21)	14.4 (11)	14.8 (4)
	B	3.3 (998)	5.8 (998)	7.5 (980)	8.3 (897)	8.8 (734)	9.3 (446)	9.8 (181)	10.3 (61)	10.5 (18)	14.6 (1)
	C	3.3 (237)	5.9 (200)	7.8 (81)	8.9 (29)	9.4 (6)					
Yellow perch	A	3.8 (23)	5.9 (23)	7.1 (23)	8.0 (23)	8.9 (23)	9.8 (23)	10.7 (23)	11.4 (23)	12.3 (18)	12.9 (12)
	B	4.0 (853)	5.9 (853)	6.8 (827)	7.7 (520)	8.4 (283)	9.5 (122)	10.6 (50)	12.0 (13)	11.7 (2)	13.2 (1)
	C	3.5 (590)	5.7 (402)	7.0 (189)	8.0 (43)	9.2 (13)					
Smallmouth bass	B	3.5 (85)	6.7 (85)	10.2 (85)	12.9 (81)	14.7 (64)	16.1 (34)	16.7 (18)	17.1 (5)	17.3 (1)	17.5 (1)
	C	3.3 (24)	7.6 (24)	11.0 (20)	13.7 (13)						
Largemouth bass	B	4.0 (299)	9.2 (301)	12.8 (289)	15.0 (253)	16.4 (170)	17.5 (92)	18.4 (42)	18.8 (22)	17.3 (15)	
	C	3.8 (573)	9.2 (375)	12.2 (201)	13.8 (64)	14.9 (14)					
Chain pickerel	B	6.0 (123)	11.4 (123)	15.8 (118)	19.1 (89)	21.7 (47)	23.6 (25)	24.8 (11)	25.7 (2)		
	C	6.8 (440)	13.5 (310)	17.3 (142)	20.0 (40)	21.2 (9)					
Black crappie	B	3.1 (52)	5.3 (52)	6.7 (52)	7.7 (49)	8.4 (42)	9.0 (21)	9.5 (11)	10.5 (3)	11.2 (1)	11.7 (1)
	C	2.8 (4)	5.0 (4)	7.9 (4)	8.8 (4)	9.7 (3)					

catch of this species during the period 1954-58. In 1954, 3,189 black crappies were harvested, followed by a take of 850 in 1955, with even fewer taken in subsequent years. Average size of harvested black crappie increased during this period from 0.34 to 0.61 pounds as did the annual growth increment, indicating a decline in abundance.

Largemouth bass

In Quabbin Reservoir largemouth bass attain the legal size of 10 inches sometime during their third year of life, as indicated by the 884 specimens analyzed (Figure 1, Table 1). Growth rate, as indicated by these fish, declined over the 1947-58 period. The same trend was reflected in a decline in average size and an increase in the number caught. Annual average weight of largemouth bass harvested between 1954 and 1958 was 1.95, 1.74, 1.13, 1.36, and 1.52 pounds, respectively, and harvest increased from 1,576 fish in 1954 to 2,064 fish in 1958.

Smallmouth bass

Growth of smallmouth bass, based on 121 individuals, was slower and showed a different trend than that displayed by the largemouth bass (Figure 1, Table 1). While minor fluctuation occurred between 1946 and 1954, the growth trend accelerated for the later year classes. The take of smallmouth bass declined for 2 years after 1954, when the maximum harvest of 689 fish was recorded. Thereafter, the catch rose, regaining about one-half of the maximum by 1958. Average size varied from 1.28 to 1.83 pounds irrespective of the numerical harvest.

Chain pickerel

Chain pickerel attain the Massachusetts legal size of 14 inches at the beginning of their third year of life (Figure 1, Table 1). Rate of growth is relatively rapid in comparison with that reported by Stroud (1955), Webster (1942), Grice (in press), and Smith (1951). Although growth of this relatively short-lived species appears to have accelerated in recent years, long-term trends are perhaps masked by the effects of dominant year classes. For example, there was a six-fold increase in the catch of chain pickerel in 1956 (3,279 in number) over the previous year, followed in 1957 by an almost equally drastic decline. This maximum catch consisted predominantly of a year class spawned in 1954. Average size of all chain pickerel harvested in 1956 averaged 1.06 pounds as compared to a range of values for the 4 other years of the study of 1.32 to 1.65 pounds.

Trout

Between 1952 and 1957 a total of 290,137 lake trout, consisting mostly of fingerlings, were stocked. Lake trout first appeared in the harvest in 1956 when 67, averaging 1 pound, were caught. Ten of these were returned to the reservoir because they were under the 18-inch size limit. The following year (1957) 636, weighing 1,565 pounds, were harvested. These fish averaged a little under 2½ pounds. Fifty-one sub-legals were also reported. In 1958 a total of 1,340 lake trout, weighing 4,964 pounds, were harvested, and 621 of sub-legal size were reported. Average weight of legals was 3.7 pounds and the range was 2 to 6½ pounds in weight. Lake trout up to 8½ pounds were reliably reported, although not census registered.

Prior to the establishment of a significant smelt population in 1956, the lake trout attained average lengths of 8.6, 12.5, and 15.6 inches at 2, 3, and 4 years of age, respectively (Figure 2). With a plentiful supply of smelt, average lengths were 10.6, 14.5, and 18.3 inches for the same respective years of life. Rapid and more accelerated growth of each succeeding year class of lake trout parallels the continued build-up in the smelt population, even though the trout population is evidently increasing.

The same relationship is borne out by an analysis of the growth rate of 146 wild brown trout. Prior to the establishment of a significant smelt population in 1956, brown trout averaged 7.7, 13.8, 15.7, and 19.7 inches at 2, 3, 4, and 5 years of age, respectively. Lengths of 8.8, 16.6, 18.4, and 21.5 inches were attained for the same respective ages.

Wild brown trout abundance is limited. Angler harvest has ranged from 98 to 828 annually. The majority have exceeded 2 pounds in weight, however, with many in the 4- to 10-pound trophy-size category. Brook and rainbow trout are also present, but brook trout are limited to the tributaries or their confluences, and rainbow trout do not reproduce either in the reservoir or its tributaries. All three species have been fin-clipped and

stocked on a token scale in recent years and the brown and rainbow trout have demonstrated growth similar to that discussed for wild brown and lake trout.

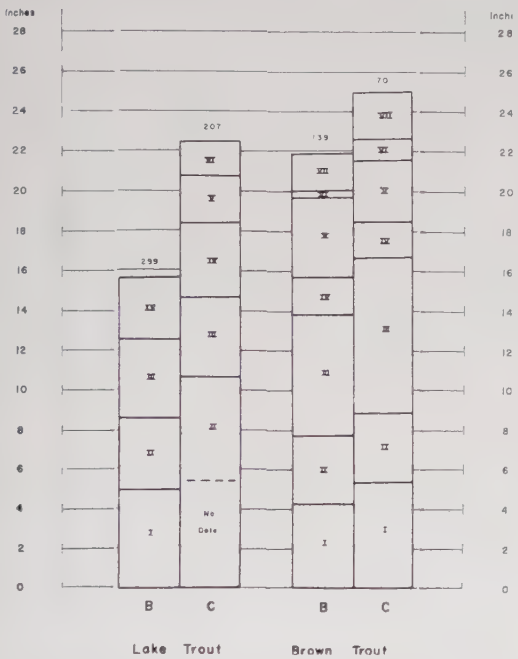

FIGURE 2.—Growth of lake trout and brown trout in Quabbin Reservoir, Massachusetts: B— before abundance of smelt; and C— after abundance of smelt. Numbers over columns indicate number of scale readings made; lengths are total lengths in inches at the end of the year of life indicated by the Roman numerals.

DISCUSSION

Failure of yellow perch to show increased growth rate during the initial years of flow-age may reflect lack of scales from year classes spawned in the period 1939-41. Rapid growing fish from these year classes could have been expected to have disappeared from the population before initiating collections in 1954. On the other hand, the growth rate found may have been typical of the reservoir from its beginning because of the relatively long period (7 years) required for filling.

The marked increase in the average size of white perch harvested in 1958 may, as in the case of the trout, be the result of the abundance of smelt. The acceleration in calculated growth increment for white perch during the last 2 years, and the fact that the species has maintained a relatively constant numerical ranking in the harvest, argues for a beneficial relationship with smelt. There is spatial overlap of this pelagic species with smelt and many white perch examined in 1958 were gorged with smelt.

It is apparent from the success of the smelt and rapid growth of brown, rainbow, and lake trout that Quabbin Reservoir is better suited to these species than to the indigenous native and exotic warm-water species. Black crappie, smallmouth, and largemouth bass originally were introduced from other regions of the country. White perch were indigenous only by nature of prior marine transfer. Even the brown and rainbow trout constituted exotics, neither of which were able to attain abundance necessary in exploiting the cold-water habitat to maximum advantage. Natural abundance of stream trout probably rests with failure of the rainbow trout to reproduce and limited tributary stream habitat for the brown and brook trout.

LITERATURE CITED

COOPER, G. P. 1941. Biological survey of lakes and ponds of the Androscoggin and Kennebec River drainage systems in Maine. Maine Dept. Inland Fish. and Game, Fish. Surv. Rept. 4: 122-154.

GRICE, F. In press. Elasticity of growth of yellow perch, chain pickerel, and largemouth bass in some reclaimed Massachusetts waters. Trans. Am. Fish Soc.

HILE, R. 1941. Age and growth of rock bass, *Ambloplites rupestris* (Rafinesque) in Nebish Lake, Wisconsin. Trans. Wisc. Acad. Sci., Arts, and Lett., 48: 189-337.

MCCAIG, R. S., J. W. MULLAN, AND C. O. DODGE. In press. A five year report on the development of the fishery of a 25,000-acre Massachusetts domestic water supply reservoir. Prog. Fish-Cult.

REED, C. H. 1947. The character of Quabbin Reservoir water during reservoir filling. Jour. N. E. Water Works Assoc., 1947: 181-201.

SMITH, R. F. 1951. New Jersey fisheries survey, lakes and ponds, Report 2: 187-193.

STROUD, R. H. 1955. Fisheries report for some central, eastern, and western Massachusetts lakes, ponds, and reservoirs, 1951-1952. Mass. Div. Fish. and Game, Boston. 447 pps.

VAN OOSTEN, J. 1929. Life history of the lake herring (*Leucichthys artedi* LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. Bur. Fish., 44: 265-428.

WEBSTER, DWIGHT A. 1942. The life histories of some Connecticut fishes. A fishery survey of important Connecticut lakes. Conn. State Pub. Doc. 47. Bull. 63: 122-207.

Utilization of Mayflies and Caddis Flies by Some Mississippi River Fishes[1]

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ABSTRACT

At sampling stations in the Mississippi River near Keokuk, Iowa, during 1958 mayfly naiads, *Hexagenia* spp., comprised over 50 percent by volume of the food of channel catfish *(Ictalurus punctatus)*, freshwater drum *(Aplodinotus grunniens)*, mooneyes *(Hiodon tergisus)*, goldeyes *(Hiodon alosoides)*, and white bass *(Roccus chrysops)*, and over 40 percent of the food of paddlefish *(Polyodon spathula)* and white crappies *(Pomoxis annularis)*. These naiads were also eaten by shovelnose sturgeon *(Scaphirhynchus platorynchus)*. Larval caddis flies, *Potamyia flava*, comprised over 60 percent of the food of the shovelnose sturgeon and between 10 and 20 percent of the food of mooneyes, goldeyes, and white crappies. The *Hexagenia* naiads found in the stomachs are the same kinds that ordinarily create a problem in the river communities but the nuisance species of caddis flies *(Cheumatopsyche campyla* and *Hydropsyche orris)* are not usually significant in the diets of the fish studied.

INTRODUCTION

Large emergences of caddis flies and mayflies occur at many places along the impounded waters of the upper Mississippi River during the summer months. At times of peak emergence hordes of winged adults invade many of the river towns, creating health, transportation, economic, and nuisance problems. Many of the river towns are planning to develop programs designed to either eliminate these insects or to control their numbers. The initiation of any program which might alter the numbers and distribution of the aquatic immature forms should be seriously considered only after a thorough investigation of their present distribution, ecological importance, and biology. Such a study was initiated at Keokuk, Iowa, in 1957 assisted by a grant from the National Science Foundation. This paper reports the degree to which mayfly and caddis fly aquatic stages were utilized as food by several species of fish as determined by the collection, examination, and analysis of stomach-content material.

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METHODS OF INVESTIGATION

The fish examined during this study were collected in Pool 19 of the Mississippi River in the vicinity of Burlington and Keokuk, Iowa, and in the tailwaters immediately below Lock and Dam 19, Keokuk, Iowa (Table 1). The problem of acquiring the large numbers of fresh samples necessary for this study was overcome by enlisting the aid of several commercial fishermen and fish markets in the vicinity of Keokuk and Burlington. The quantities, in percentage, of each food organism with relation to the total stomach contents of each fish species may be presented in a radial diagram where each of the five radii is 100 percent and the points on these radii are connected to form a characteristic figure (Figure 1). Although a number of species of mayflies and caddis flies were identified during the stomach-analysis work, only relatively few were important in the diets of the fish examined. A comparison of all analyses made for each fish species collected showed that little seasonal variation in food habits occurred relative to the utilization of caddis and mayfly immatures.

UTILIZATION OF MAYFLIES AND CADDIS FLIES

Mayflies of the genus *Hexagenia* form an important source of food for the paddlefish during the winter, spring, and early summer months. Naiads of *Hexagenia* comprised 46 percent of the total food content of the 64 paddlefish examined. Cladocerans, copepods,

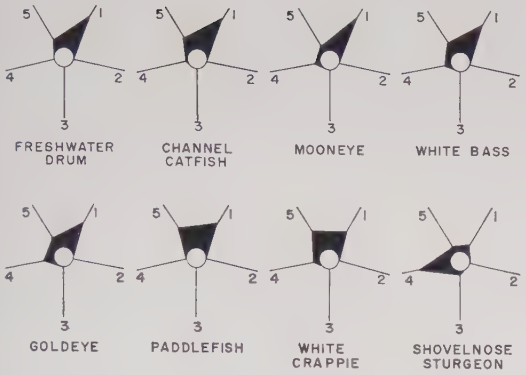

FIGURE 1.—Utilization of mayflies, *Hexagenia* spp. (1); caddisworms, *Hydropsyche orris* (2); *Cheumatopsyche campyla* (3); *Potamyia flava* (4); and other organisms (5); as food by fish, Mississippi River, near Keokuk and Burlington, Iowa, January 1958 to November 1958.

and algae were also significant food items, primarily in the late summer and fall months. Shovelnose sturgeon depend largely upon caddis larvae throughout the year. In the 74 sturgeon examined the total content was 68 percent *Potamyia flava* larvae, 7 percent *Cheumatopsyche campyla* larvae, 17 percent *Hexagenia* naiads, and 8 percent other material which included immature Plecoptera, Diptera, and Odonata. The total stomach content of 136 mooneyes included 66 percent *Hexagenia* naiads and 17 percent *Potamyia flava* larvae. Immature Plecoptera, Diptera, and Odonata comprised the remainder. The food habits of the goldeye are almost identical to those of its more abundant relative, the mooneye. *Hexagenia* naiads comprised 56 percent of the contents of the 44 goldeye stomachs collected; *Potamyia flava* larvae made up 19 percent. Immature Zygoptera and Odonata and fish formed the bulk of the remaining contents. The stomach contents of 143 channel catfish contained 68 percent *Hexagenia* naiads and subimagos but only 3 percent *Potamyia flava* larvae. Mayfly subimagos appeared only in channel catfish stomachs collected between June 24 and July 16 and their presence always coincided with periods of peak mayfly emergence. The remainder included immature Plecoptera and Diptera, clams, snails, and algae. *Hexagenia* naiads comprised 54 percent of the total stomach content of the 56 white bass collected. The larvae of *Potamyia flava* formed 9 percent of the content and immature Odonata and Zygoptera, Hemiptera, amphipods, crayfish, and fish were also present. The food of 83 white crappies included 42 percent *Hexagenia* naiads and 11 percent *Po-*

TABLE 1.—*Fish collected in the Mississippi River at Burlington and Keokuk, Iowa, in 1958 for food-habits study*

Species	Collection dates	Numbers with food	Gear	Total lengths of fish in inches[1]
Paddlefish	January and February	17	Gillnet	29.0-54.5
	April	24	Seine	
	July and August	10	Seine	
	October and November	12	Seine	
Shovelnose sturgeon	April	44	Trammel net	17.5-24.0
	June and July	10	Hoop net	
	October	20	Trammel net	
Mooneyes	April	36	Seine	8.5-14.5
	July and August	33	Seine	
	October and November	67	Seine	
Goldeyes	July and August	39	Seine	10.0-15.5
	October	4	Seine	
Channel catfish	April	14	Seine	9.5-21.5
	June	39	Trot line	
	July and August	68	Trot line	
	October	9	Seine	
White bass	April	8	Seine	8.0-14.5
	July and August	35	Seine	
	October and November	14	Seine	
White crappie	April	4	Seine	6.6-12.3
	July and August	76	Seine	
	October	2	Seine	
Freshwater drum	April	4	Seine	8.5-14.5
	July and August	18	Seine	
	October and November	11	Seine	

[1]Shovelnose sturgeon were measured in standard lengths. Paddlefish were measured from the tip of the bill to the end of the dorsal portion of the caudal fin. Total lengths of all other fish were measured from the anterior of the head (mouth closed) to the longest ray of the caudal fin (lobes compressed) while the fish lay on its right side.

tamyia flava larvae. The remainder of the content was composed chiefly of immature Diptera, Odonata and Zygoptera, Hemiptera, and fish. Seventy-five percent of the total stomach content of the 33 freshwater drum examined was comprised of *Hexagenia* naiads. Immature Coleoptera and Odonata, snails, and fish constituted the bulk of the remaining 25 percent.

The stomach analyses show that, with respect to mayflies, the nuisance species are the same as those which are important as fish food in their immature stages. With regard to caddis flies, however, the problem species *(Cheumatopsyche campyla* and *Hydropsyche orris)* are apparently not significant as food organisms in the fish examined. In this case another caddis fly, *Potamyia flava,* closely related to *H. orris* and *C. campyla* both biologically and taxonomically, has little importance as a nuisance species because it does not enter cities or residential areas in large numbers but is relatively significant as a source of food for many of the fish, especially the shovelnose sturgeon.

ACKNOWLEDGMENTS

The author wishes to extend his appreciation to the many commercial fishermen and fish-house operators, whose interest and assistance made this study possible. Thanks are due the personnel of Lock and Dam 19 and the Corps of Engineers, U. S. Army, for providing laboratory space and assistance and to the City of Keokuk for lodging during the periods of field investigation. The author is indebted to Dr. Kenneth D. Carlander for guidance and critical comment in preparation of the paper and to Calvin R. Fremling for field assistance.

Some Influences of Domestication upon Three Stocks of Brook Trout (*Salvelinus fontinalis* Mitchill)

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ABSTRACT

Three stocks of brook trout—domestic, wild, and first generation removed from wild stock—were tested and observed for effects of domestication. The domestic stock had been selectively bred for 90 years, whereas the wild stock came from an isolated lake in the Adirondack Mountains. To reduce differential environmental influence to a minimum, the three lots were reared from eggs in adjacent rearing troughs at the same water temperature. After 1 year under these hatchery conditions the domestic fish were 5.2 inches in length and the wild, 3.6 inches. Throughout the rearing domestic stock were tamer and exhibited less fright than wild-stock fish. Laboratory tests showed that wild stock could stand a greater concentration of accumulated metabolites, that they could endure higher water temperature, and that domestic stock had a surface response whereby they moved to the surface of a rearing trough or a tall aquarium. Domestic fish also lacked the desire to conceal themselves. Stamina tests conducted by swimming 1,522 fish individually until exhausted in a small trough showed that the wild stock had greater stamina throughout the size range tested. Survival trials in a small stream and a pond indicated that wild fish experienced less mortality and had growth rate similar to or better than domestic fish in both habitats. After 73 days in the small stream 20 percent of the domestic and 33 percent of the wild stock survived. Domestic fish grew 0.34 inches and wild fish, 0.48 inches. Survival was 43 percent for the domestic and 65 percent for the wild after 108 days in a pond, while length increase was 2.6 inches for the domestic and 2.5 inches for the wild stock. The domestic increased more in weight. After being in a pond for nearly 4 months, the domestic stock had acquired little wariness.

INTRODUCTION

One of the first books on trout culture, *Domesticated Trout*, was written by Livingston Stone in 1873, and indeed it was a portent of impending events. To a limited extent the implications of the title were conceived by Stone for he wrote:

> The time may come when continued domestication, together with the overcoming of their [fish's] fear of man, will so modify the present action of their instincts, that, when pains are taken with domesticated trout, they will *prefer* to seek the shelter and food which they find around the homes of men to the precarious chances of a wild roaming life. This may not be probable, but I do not think it is impossible.

It is now apparent that with the existing mass culture and widespread selective breeding programs, hatchery trout cannot avoid diverging from their wild ancestors.

Influence of fish culture on trout is manifest in two ways: genetical and environmental. Selective breeding has received most attention from fish-culturists, while fisheries biologists have been more interested in the environmental effect.

Unintentional selective breeding takes place in all hatcheries. Fish that are easier to handle, that appeal to the fish-culturist as having a "nice shape," or that grow better under hatchery conditions are unconsciously favored.

Intentional breeding programs have been conducted for many years. The most common selected characteristics have been faster growth, earlier maturity, greater egg production, earlier spawning, and disease resistance. From this list it seems that evident features of selective breeding are a benefit to the fish-culturist but of unknown "value" to the fish. Many breeding programs have been eminently successful in the desired intentions. However, for self-sustaining populations, fish free from selective breeding or bred for maximum survival under natural conditions may prove more desirable.

Hatchery environment can influence fish in many ways as noted by Schuck (1948). The effect of hatchery rearing upon survival in natural waters was investigated by Needham

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and Slater (1944), Needham (1949), Eipper (1953), Wales (1954), Nielson *et al.* (1957), Smith (1957), Miller (1958), and others. In addition, the importance of hatchery environment is demonstrated by higher survival of fish which are conditioned to stream habitat prior to stocking (Schuck and Kingsbury, 1948; Miller, 1957).

As expressed in the preceding paragraph, the effects of the environment upon trout have been investigated but the effects of genetical changes fostered by domestication upon behavior and survival have seldom been explored. Green (1952) stocked Stillwater Pond, New York, experimentally with wild- and domestic-stock brook trout. He found higher survival the second and third year for wild stock, as well as differences in body shape, color, and wildness. Webster (1954) also found indications of different survival of wild and domestic stocks.

The objectives of the research presented in this paper are (1) to discover some of the areas in which physiology and behavior differ between a domesticated and a wild stock of fish when environmental variation is reduced to a minimum, and (2) to see if these dissimilarities influence survival in a harsh and in a mitigated natural environment. The former was determined by laboratory experiments and the latter by limited field trials.

TEST FISH

To accomplish these objectives it was necessary to acquire a domesticated stock of trout, a wild stock, and preferably a third stock as a control. Furthermore, these trout had to be reared under similar conditions in the same hatchery.

Stocks of fish

For a domestic strain a stock of brook trout was secured that had been reared in hatcheries for approximately 90 years. The selection program in early years had been to save "the best" of the 2-year-olds each year for brood stock. Later, emphasis was placed on selection for earlier spawning, and after 20 years the spawning date was advanced by 15 days. Other characteristics stressed in selection were faster growth, better shape, and disease resistance.

Honnedaga Lake, located in the southeastern Adirondack Mountains of New York State, was the source of wild fish. The following information concerning Honnedaga Lake was given by Webster (1951, 1957). The lake has a total alkalinity of less than 2 p.p.m. and a pH about 5. These conditions are unusual for a lake of about 800 acres in this region. Surface temperature rarely reaches 70° F. Brook trout are the only native fish, but several other species were temporarily established by the 1920's only to disappear later. A few lake trout *(Salvelinus namaycush)* possibly still remain as a relic population. It is likely that the peculiar environmental conditions of the lake are lethal to most introduced fish within a short time. This would be conducive to a strong inbred selection among the native trout, tending to keep the race genetically pure.

The Honnedaga brook trout are tentatively described as being slow-maturing and long-lived; 2- to 6-year-old fish are not unusual. Two- to three-pound fish are common in the spawning population.

The third lot of fish came from hatchery-stock brook trout that had spent 1 year in a lake (Long Pond near Brandon, New York) immediately previous to spawning. Originally the stock came from several commercial hatcheries in Pennsylvania and New England. This first-generation stock acted as a reference lot although it was of unknown genetic origin.

Throughout the remainder of this paper the three strains of test fish will be referred to as domestic, first generation, and wild.

Hatchery procedure

All three lots of fish were trough-reared in the Cornell University Experimental Fish Hatchery. Lots were interchanged each 2 weeks among three adjacent troughs. This reduced possible differential influences of light, accumulated waste products, and fright from human interference. Water temperature was nearly uniform among the troughs, usually within 1° and never varying more than 2° F. All fish were fed the regular diet used in the hatchery: liver when small and, as they grew larger, a mixture of 40 percent liver and 60 percent Cortland No. 6 meal. Fish used in experiments were not fed the 24 hours before a test.

All length measurements are fork lengths recorded to the nearest tenth of an inch (with

one noted exception). Weights are recorded in pounds and tenths of pounds.

Fish used in laboratory tests were given a temporary mark by clipping the dorsal or ventral lobe of the caudal fin. Ventral and pectoral fin clips are designated by V and P.

Development, growth, and mortality in hatchery

Egg diameter was 0.173 inches for the domestic, 0.165 inches for the first generation, and 0.189 inches for the wild stock. Development chronologically was similar in all three lots, with the majority of the fish hatching within a 2-week period. The domestic stock was more advanced until approximately January 1 when the other two lots were placed in warmer (50° F.) water which helped to equalize development. One possible source of differential influence was the rearing of domestic stock until the advanced-eyed stage in a different hatchery and at slightly higher water temperatures. Since it would be nearly impossible to find three widely different stocks of brook trout that spawn at the same time, temperature manipulation during early development was used to equalize the time of hatching.

Growth in length of fish of the three stocks was similar the first 80 days, after which divergence increased (Figure 1). An important factor relative to growth in the hatchery is the phlegmatic behavior of the domestic trout and the excitable nature of the wild trout. Fry of all three stocks showed little sign of fright until they were nearly an inch long and were feeding well. Then for a month (February 28 to April 3) all could be frightened easily. By April 22 the domestic and first generation fish were calmer. Throughout the remainder of the summer the wild fish were more easily frightened by human presence, a shadow, or a hand placed in the water. The domestic fish were docile and when a finger was placed in the water they often nipped it, giving the impression they were "at home" in the hatchery trough (Figure 2).

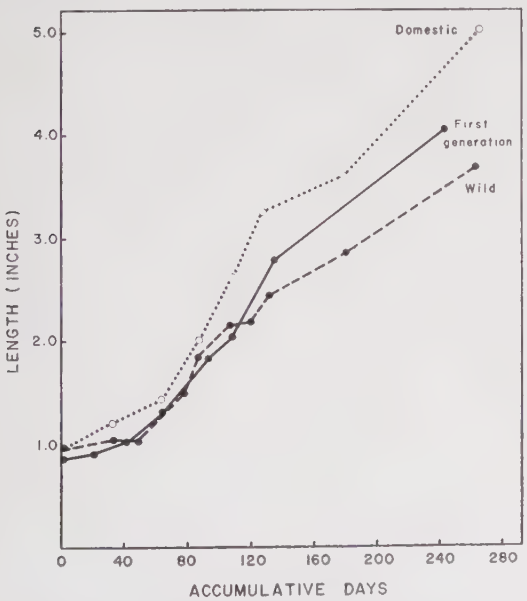

FIGURE 1.—Growth of three stocks of brook trout in Cornell University Experimental Fish Hatchery.

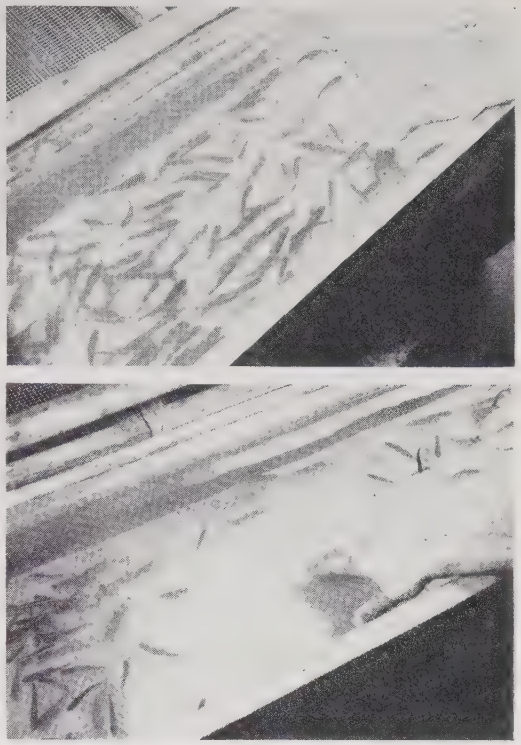

FIGURE 2.—Domestic fish (above) were not frightened by placing a hand in the trough; wild fish (below) show avoiding reaction.

Condition factors from measurements taken on November 15, when the domestic fish were 5.19 inches and the wild 3.65 inches, were 54.05 for the former and 38.58 for the latter. Casual inspection clearly showed that the wild trout were slimmer.

Mortality was heavy in all three lots. From egg take to approximately 1 year, it was 93 percent for the domestic, 62 percent for the first generation, and 64 percent for the wild. The poor quality of the Cornell University Hatchery water supply attributed to much of this high mortality. Early mortality may be important because of the possible selection to which the remaining individuals have been subjected. A population which has suffered heavy mortality may be composed of hardier individuals than a population that has experienced low mortality. Wales (1954) discussed Pacific salmon as having 90 percent mortality in wild populations, but pampered hatchery fish as having a much lower death rate until stocked after which an equalization mortality occurred. In the present situation selective early mortality would tend to favor fish of the domestic stock for they had a higher rate than either the other two.

LABORATORY EXPERIMENTS

Effects of metabolites

Five trials were conducted to determine the comparative mortality caused by high metabolite concentration. Test containers were a series of 1,000-milliliter beakers nearly submerged in running water. Each beaker was aerated by oxygen. An equal number of fish from each lot was put in the same beaker. Fish length was 1.7 inches in Trials I to III and 2.9 inches in Trials IV and V. When approximately 50 percent of the fish in a beaker had died, all fish were removed and counted. Two to three hours were required to reach this mortality level.

The data from these trials (Table 1) indicate a wide difference in the ability of fish of the three lots to withstand accumulated metabolic wastes. Approximately 51 percent of the domestic, 50 percent of the first generation, and 20 percent of the wild fish died.

The obvious factor to which this differential susceptibility might be attributed is general hardiness or well-being of the fish. The relationship between head size and efficiency of elimination of body waste was not realized at the time the tests were conducted. Later, several papers stimulated further investigation. Graham (1956), while working on fresh-water alewives *(Alosa pseudoharengus)*, suggested that since osmotic exchange takes place through the gills and oral membranes the large-headed individuals have an advantage in osmotic regulation. Keys (1931) found that large-headed killifish *(Fundulus parvipinnis)* could withstand adverse conditions such as decreased salinity or oxygen deficiency better than small-headed individuals. A small head is characteristic of many faster-growing fish (Martin, 1949; Tester, 1937).

Although the fish tested could not be measured, two other groups were available: yearlings from the same lots and fingerlings similar in length to the test fish of a later year class from the same two stocks. Fifteen domestic fingerlings and yearling fish from the two lots were 1.6 and 6.3 inches in mean length; 15 wild fingerlings and yearling fish were 1.7 and 4.0 inches in mean length. The following six measurements were taken:

Fork length—tip of snout to caudal fork.
Body width—at widest part of body.
Body depth—at deepest part of body.
Head length—tip of snout to posterior margin of opercular membrane.
Head width—distance between normally appressed preopercles.

TABLE 1.—*The mortality of three groups of confined brook trout in response to accumulated metabolic wastes*

Trial number	Water temperature (degrees F.)	Stock of fish					
		Domestic[1]		First generation		Wild	
		Number	Mortality	Number	Mortality	Number	Mortality
I	52	20	11	—	—	20	4
II	51	40	18	40	22	40	7
III	52	20	10	20	8	20	3
IV	56	7	4	—	—	7	3
V	56	7	5	—	—	7	2
Total		94	48	60	30	94	19
Percentage		—	51	—	50	—	20

[1]Chi-square (domestic and wild) = 12.56, $P < 0.01$.

TABLE 2.—*Maximum temperature tolerance of three lots of brook trout when temperature was raised to maximum (80° F.) in 5 hours*

Trial number	Water temperature (degrees F.)	Stock of fish					
		Domestic[1]		First generation		Wild	
		Number	Mortality	Number	Mortality	Number	Mortality
I	52	10	10	10	6	10	0
II	54	20	10	20	4	20	4
III	60	20	15	20	11	20	4
IV	58	15	10	15	6	15	8
Total		65	45	65	27	65	16
Percentage		—	69	—	42	—	25

[1]Chi-square (domestic and wild) = 15.76, $P < 0.01$.

Head depth—distance on a vertical line immediately posterior to the eye.

All measurements were made with calipers to the nearest tenth of a millimeter.

The three body measurements for each fish were added and the same was done to the head measurements. To compute a head-to-body ratio the sum of the three head measurements was divided into the sum of the three body measurements. The mean head-to-body ratios were:

	Domestic	Wild
Fingerlings	2.661 ± 0.060	2.589 ± 0.031
Yearlings	2.880 ± 0.139	2.676 ± 0.090

Both of these groups have a head-to-body size ratio that is different at the .05 level as measured by a rank-sum test. This agrees with the above references in that the faster-growing individuals in these two stocks of brook trout had smaller heads. Thus, the wild stock had a greater area over which to regulate osmotic balance.

High temperature tolerance

Extreme temperatures have been reported (Huntsman, 1942, 1946; Gunter, 1947) as the cause of fish mortality in natural situations. Ultimate lethal temperatures become important when marginal waters are utilized for trout. This is especially true if high water temperatures restrict over-summer survival. When some brook trout required 7 days to die at 79.7 to 83.3° F., Embody (1921) thought that perhaps all strains of brook trout might not be able to stand these high water temperatures.

Temporarily-marked test fish, 1.9 inches long, were placed in a 20-gallon glass aquarium. Water temperature was raised to 80° F. (the chosen maximum temperature) in 5 hours by running a stream of temperature-controlled water into the aquarium. As soon as motility was completely lost, a fish was considered dead. The intent was to terminate the test at 50 percent mortality, but due to periodic checks it was not always possible to stop the test at the prescribed time so a greater mortality occurred in some instances. Table 2 shows that the wild stock had less mortality than either of the others.

Domestic brook trout reared on a hatchery diet have a higher fat content than wild brook trout from natural waters. Not only is the fat content higher but it is more saturated (Phillips *et al.*, 1955). To continue the relation of fat to lethal temperatures one step further, resistance to temperature extremes may be changed by feeding different fats to goldfish (Hoar and Cottle, 1952). This was true even though the fish appeared to be in excellent condition. As will be shown later in this paper, wild fish utilize a hatchery diet differently than domestic fish; the amount and type of fat present could be one factor that reduces the temperature tolerance of domestic trout.

Surface response

A noticeable difference during the rearing was that fish of the wild stock had a tendency to remain near the bottom of their trough while domestic fish were spread vertically throughout the water. This was true even when the groups were undisturbed.

To investigate this surface response the following test was used. Test fish were placed in a tall glass tank measuring 36 by 6 by 4 inches; water was homothermous and

light was of even intensity. During some tests a glass plate covered the open top of the tank, but in other tests it was removed. Reactions of the fish were the same either way (Figure 3). Fish used in Trials I to V were 1.6 inches long; those in Trials VI and VII, 2.8 inches. Five marked fish from each lot (a total of 15) were placed in the tank and a count of the top five was taken every 10 minutes until the end of the test. In two tests only the wild and domestic fish were used. All three stocks were used in the other five. In each of the seven trials more domestic fish were counted near the surface than wild ones (Table 3). Twice as many domestic (50 percent) as wild (26 percent) were counted in the top five fish. First-generation fish behaved much like the domestic.

The main hydrostatic organ is the air bladder which equalizes density of the fish with that of the environment. In many bottom-dwelling forms the air bladder is reduced, and in intertidal species, often absent; it is best developed in limnetic or pelagic forms (Jones, 1957). Jones also attributed the movement of gas in and out of the air bladder to stimuli caused by exteroceptors. Could domestic trout that have spent many generations in shallow raceways and rearing ponds have been selectively adapted to this low-pressure artificial environment, or could the exteroceptors through lack of use have been dulled? Threinen (1958) mentioned this same point in relation to planting hatchery rainbow trout in lakes. He found that if the fish were liberated 20 feet below the surface they immediately came to the top. Also, when stocking in ponds containing a warm epilimnion, 15 feet was as deep as the fish would dive before returning to the surface. Heavy mortality frequently resulted if the thermocline was below 15 feet.

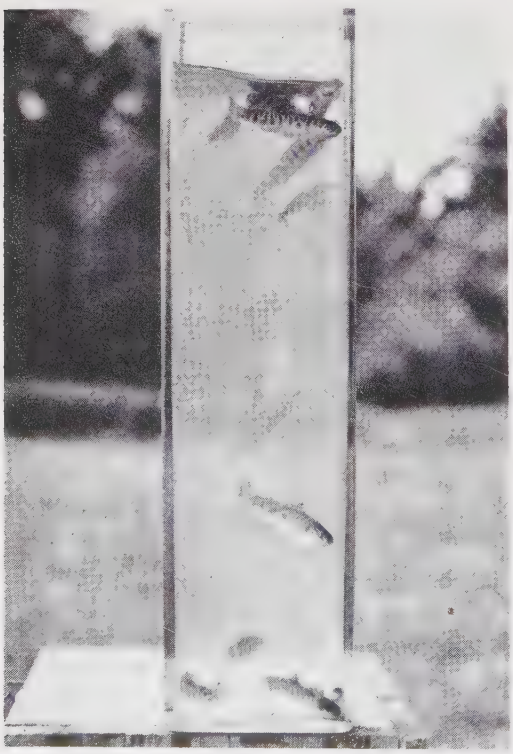

FIGURE 3.—Surface response of two lots of brook trout in a tall aquarium. Domestic fish are near top; wild fish near bottom.

TABLE 3.— *A summary of the surface response of three lots of brook trout in a tall aquarium*

Item	Stock of fish		
	Domestic[2]	First generation	Wild
Number of fish per trial	5	5	5
Number of trials	7	4	7
Total observations	35	28	35
Total possible observations[1]	175	140	175
Total fish in top 5 counts	88	51	45
Percentage of fish in top 5	50	36	26

[1]Number of fish per trial × total observations.
[2]Chi-square (domestic and wild) = 14.36, $P < 0.01$.

Concealment

A small glass aquarium containing several rocks was used to test hiding reaction. Regardless of how many times the test was repeated, domestic fish made no pretense at hiding but remained fully exposed. Wild fish would immediately seek concealment, rarely venturing into the open.

Stamina

Schuck (1948) listed lack of exercise for hatchery fish as a cause of mortality. Black (1957), in his lactic acid work, wrote that muscular fatigue reduces maximum swimming speed, breaks up schooling behavior, and changes fish behavior from escape to hiding. Exercised coho salmon *(Oncorhynchus kisutch)* showed less susceptibility to fatigue and an increased cruising speed compared to fish that were raised in hatchery troughs (Brett *et al.*, 1958). Hatchery cutthroat trout *(Salmo clarki)* reared in a stream before stocking in a test stream area had better survival than fish reared in a pond (Miller, 1954).

Vibert (1956) used the ability of fish to maintain themselves in a strong current as one of his tests for hardiness. He utilized this test to determine the influence of hatching eggs by the usual hatchery procedure as opposed to hatching them under a layer of gravel. This method could be used, he suggested, as a test of other hatchery practices. In California Reimers (1956) used a 20-foot metal hatchery trough and a controlled current of 0.5 to 3.0 feet per second to test fish stamina. He found that hatchery-raised rainbow trout *(Salmo gairdneri)* were the weakest, stream-conditioned rainbow trout next, wild brown trout *(Salmo trutta)* the strongest.

A small, galvanized metal trough 43 inches long, 2.5 inches wide, and 3 inches deep was used as the testing apparatus (Figure 4).

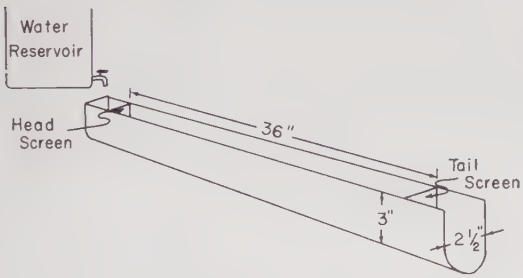

FIGURE 4.—Testing trough used for stamina trials.

It had a rounded bottom to reduce slow current areas. A ¼-inch-mesh, fine wire screen was placed near the lower end and another was placed 5 inches below the water source. These two screens confined the fish into a 3-foot section of fairly uniform and laminar water flow. Water was pumped with a small electric pump out of the rearing trough containing fish to be tested and into a small reservoir. A constant head was maintained by keeping this reservoir full; a small valve regulated flow into the testing trough. The slope of the testing trough could be changed by ⅛-inch adjustments on either end. Water velocity in the several tests varied between 0.3 and 3.0 feet per second.

Extreme care was taken to see that fish of each size range from each group were tested under the same water conditions. Throughout the testing, water temperature in the testing trough and in the rearing trough were the same for any one test.

It was impossible to maintain the same water flow and water velocity throughout the test series. Fish length increased from less than an inch to over 3 inches during the tests. Sufficient water volume and velocity for testing the larger fish would have overwhelmed the smaller. A swimming time of at least 30 seconds and preferably 45 seconds was desired to reduce inaccuracies in timing. On the other hand, too long a swimming time (over 10 minutes) was undesirable because of the time involved and the possibility of other influencing factors aside from stamina. Water volume was increased 1.8 times when fish length was 2.2 inches to provide the larger fish with sufficient water.

This experiment was designed to test differences in stamina among the three lots of fish, not to measure the increase in stamina as fish grew. Temperature fluctuated during the test series, but all lots were tested throughout the temperature range. Restrictions imposed upon the larger fish by the confines of the trough could limit swimming efficiency.

Approximately 50 fish for each test were taken from near the head of the rearing trough and placed in a basket immediately below the testing trough. Individual fish were taken from the basket and placed in the testing trough. As the small net used for the transfer was put in the testing trough, it made a backwater which allowed the fish to orient itself to the current. When the fish was facing the head of the trough (usually within 1 or 2 seconds), the net was removed and an assistant started a stop watch. Occasionally a light touch with a glass rod was needed to keep the fish swimming.

Behavior of fish within the testing trough usually followed a standard pattern. Orienta-

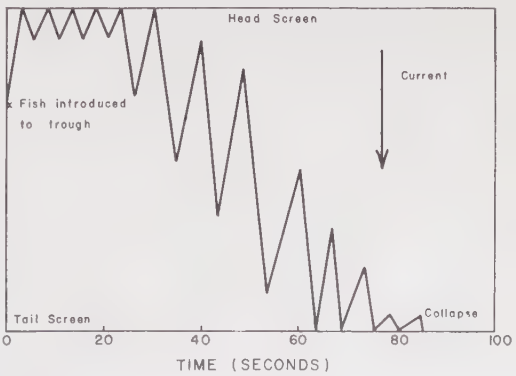

FIGURE 5.—Schematic presentation of fish movement in testing trough. Fish length, 1.5 inches.

tion to the current was immediate except in a few cases where the fish swam to the tail screen. These individuals were removed and excluded from the test. Fry and Hart (1948), in quoting Roger's unpublished work on goldfish, stated that 6 out of 82 goldfish refused to swim so were discarded, while Brett *et al.* (1958) had to remove one tenth of their test fish because of inconsistent behavior.

Vigorous swimming followed orientation with fish butting their noses against the head screen. Then followed a series of downcurrent drifts and swimmings back to the head screen (Figure 5). The drifts lengthened each time until, when at approximately the midway point in the trough, the upstream burst of swimming was not long enough to carry the fish to the head screen. As fatigue increased, body movements became exaggerated. The first time or two the fish's caudal fin touched the tail screen there was vigorous response and upstream progress was often past the midway point. Soon tactile response lessened, and frequently collapse was sudden and complete with the fish making no attempt to resist the current; they were then held crosswise against the screen. (Both the quick collapse and reduced tactile response were noticed by Brett *et al.* (1958) in their work on sockeye and coho salmon.) If the exhausted fish did not respond to two taps with a glass rod on the tail screen, the test was concluded.

After removal from the testing trough, the fish were allowed to recuperate overnight in a basket. Then each was measured and returned to its rearing trough.

Deviations from mean swimming time were fairly wide. Figure 6 illustrates these deviations and shows the increased spread as the

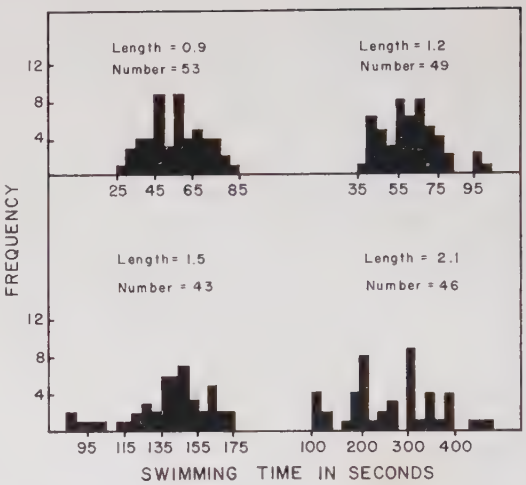

FIGURE 6.—Swimming time frequencies for four sizes of wild fish. Lengths recorded in inches.

fish become larger. A different design of testing trough might produce more constant results. Radcliffe (1950) in his work on effect of fin-clipping and cruising speed also had wide standard deviations.

Tables 4, 5, and 6 give the data on the stamina tests for each of the three groups. Altogether 1,522 fish were given individual tests. Figure 7 presents the increase in swimming time as the fish increased in length. A linear increase could be expected for Gray (1957) reported Bainbridge as finding a generally linear relation between swimming speed and length of fish when they have the same frequency of tail beat. However, more stamina trials are needed to determine if a true linear relationship exists. In Figure 7 the last two points make a sharp deflection. Values of these two points were doubled for increased clarity of presentation. There are two partial justifications for this: (1) water flow in the testing trough was nearly doubled at this

TABLE 4.—*Stamina trials of a domesticated stock of brook trout as measured by swimming under controlled test conditions*

Date	Water temperature (degrees F.)	Number measured	Mean length	Standard deviation	Number tested	Swimming time (seconds)	Standard deviation	Swimming time per inch of fish
February 24...	52	113	0.92	0.067	157	38.28	13.54	41.60
March 13.....	52	47	1.04	0.072	47	45.11	13.07	42.41
March 17.....	51	55	1.05	0.074	54	51.01	12.14	48.58
March 27.....	52	52	1.22	0.109	49	68.29	21.50	55.97
April 9.....	50	47	1.33	0.163	48	65.75	16.37	49.44
April 28.....	48	42	1.50	0.174	50	79.50	17.12	53.00
May 23.....	55	49	2.04	0.245	48	153.33	40.41	75.16
June 13.....	60	51	2.62	0.331	53	105.90	32.99	40.41
June 30[1].....	66	41	3.26	0.417	40	140.43	29.42	43.07

[1]Water flow increased 1.8 times on June 13 and 30.

TABLE 5.—*Stamina trials of a first-generation stock of brook trout as measured under controlled test conditions*

Date	Water temperature (degrees F.)	Number measured	Mean length	Standard deviation	Number tested	Swimming time (seconds)	Standard deviation	Swimming time per inch of fish
February 17...	47	94	0.87	0.045	231	36.57	11.86	42.03
March 10.....	50	46	0.94	0.062	51	51.51	9.70	54.79
March 29.....	49	46	1.15	0.126	50	49.10	10.04	42.69
April 21.....	52	51	1.30	0.459	50	61.42	17.07	47.25
May 19.....	61	44	1.84	0.562	45	160.42	26.68	87.18
June 3.....	60	52	2.19	0.489	53	202.61	25.32	92.51
July 1[1].....	66	35	2.78	0.374	39	117.07	35.68	41.03

[1]Water flow increased 1.8 times on July 1.

same time and (2) this places the points in an approximate linear position to the previous points.

The difference between the wild and domestic stocks becomes more divergent as the fish increase in size. Figure 7 shows that under these test conditions wild-stock fish have greater stamina than domestic-stock fish throughout the entire size range tested. The plot of points from first-generation fish has been omitted from Figure 7 to avoid crowding, but this group is more scattered than the other two, in general falling between them.

Stamina of the three lots of fish can be compared in relation to time (Figure 8). It could be that the faster growth of the domestic lot counteracted their reduced stamina. When testing started, all three groups were near the same stage of development, but as the domestic stock grew faster, it was larger throughout the tests. Even though smaller, wild stock had greater stamina at a given time (except for a short period) than domestic trout.

This same figure also suggests that stamina tests are indicative of the general well-being of the fish. Between April 2-9 high mortality was experienced in all three lots. Each of the three groups of test fish had a drop in stamina at this time. (Note area marked by left arrow on Figure 8.) Wild- and first-generation-stock fish showed the effects earlier than the domestic fish. Domestic fish did not begin feeding poorly until nearly a week after the other two groups were off their feed.

The abrupt decline shown by the last two points was the result of an increase in water flow in the testing trough. Even with the increased flow the confines of the testing trough probably reduced swimming efficiency as the fish grew larger. Domestic fish, being the largest, were possibly hindered more by the trough. However, the consistent results experienced throughout the size range tested suggested that trough restrictions were not masking stamina differences.

FIELD EXPERIMENTS

Field trials were limited to small controlled situations because of the exploratory nature and limited fish available. Two habitats with extreme environmental conditions (a stream and a pond) were chosen — one severe, the other mild. To intensify the influence of competitive and environmental factors, both the stream and the pond were stocked more heavily than would usually be advisable.

TABLE 6.—*Stamina trials of a wild stock of brook trout as measured under controlled test conditions*

Date	Water temperature (degrees F.)	Number measured	Mean length	Standard deviation	Number tested	Swimming time (seconds)	Standard deviation	Swimming time per inch of fish
February 27...	49	69	0.92	0.037	59	44.39	18.56	48.25
March 14.....	50	52	0.99	0.082	53	57.22	15.06	57.79
April 1.....	53	50	1.16	0.080	49	55.51	15.32	47.85
April 14.....	51	53	1.17	0.121	51	62.20	14.43	53.16
May 13.....	56	54	1.55	0.167	52	133.30	28.50	86.00
May 24.....	55	49	1.83	0.213	48	190.21	24.57	103.94
June 11.....	60	30	2.14	0.308	46	263.38	25.11	123.07
June 23[1].....	60	53	2.20	0 355	52	136.40	22.37	62.00
July 7[1].....	66	46	2.44	0.283	47	150.91	42.78	61.84

[1]Water flow increased 1.8 times on June 23 and July 7.

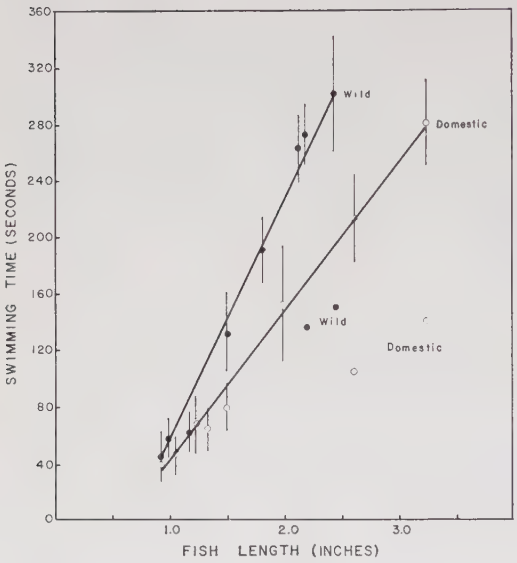

FIGURE 7.—Stamina relationship of wild and domestic stock of brook trout. Last two points on both lines were doubled to continue straight lineation. The two points for the wild and the two for the domestic which group below the lines are the original values. Vertical lines are standard deviations.

East Lake Outlet

The outlet of East Lake provided a situation for testing the survival of two lots of fish under stream conditions. This stream is located on the Adirondack League Club Preserve near Old Forge, New York, where it drains East Lake. The latter was reclaimed in 1954 and restocked with brook trout in 1955.

A 1,600-foot section of stream located 0.5 mile below the lake was used as a test section. A Wolf-type fish trap at the downstream end and an incline screen at the upstream end prohibited fish movement out of the test area. For one night (July 17) the downstream trap was only partially operative when it was damaged by high water and debris. The low catch throughout the balance of the time, including high water periods, suggests that the lack of a barrier for one night was of little consequence.

Stream width at medium water flow was 5 to 8 feet and water depth was 4 to 12 inches except for a few 2-foot-deep pockets. The bottom was almost completely rock except for scattered small sand bars and quiet silt areas. Throughout the stream course undercut banks, brushy shorelines, and fallen logs were common. A canopy, predominantly of spruce *(Picea)* and beech *(Fagus)*, shaded much of the stream. Previous to stocking, 15 small rock barriers were built to increase suitable habitat for the introduced fish. Water temperature ranged from 52 to 66° F. during the test period of June 7 to August 20, 1958.

Five hundred each of domestic (3.1 pounds) and wild fish (1.4 pounds) were planted in the stream on June 7. Further data are recorded in Table 9. Domestic fish, marked by removing the right ventral fin, were 2.41 inches in mean length; the wild, marked by removing the left ventral fin, were 2.04 inches in mean length. Fish of the same length at stocking would have been preferable as, other factors being equal, larger fish have a survival advantage.

The fish were spot planted throughout the stream. Sections of good habitat were subjectively stocked more heavily than shallow or exposed areas. Twice during the planting, resident fish darted out to catch an introduced fish immediately after it was put into the stream. Fifty fish were confined 3 days to observe any undue mortality caused by transportation or from the different water. All survived and were liberated.

Recovery of the fish was by electrofishing, using a 500-volt "Homelite" DC generator. Salt was added to increase conductivity. The stream was divided into 200-foot sections, and each section was electrofished twice. Approximately 75 percent of the fish were taken the

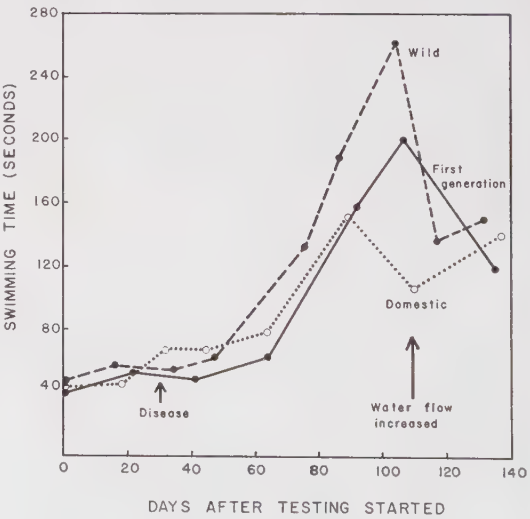

FIGURE 8.—Stamina of three lots of brook trout as related to time. Fish length ignored.

first time a section was electrofished. This made a DeLury-type estimate possible (DeLury, 1947). All fish taken from the stream were preserved in a 10 percent formalin solution for conventional processing and enumeration after returning to the laboratory.

On August 20, after being in the stream for 73 days, 94 domestic trout (0.6 pounds), 144 wild trout (0.5 pounds), and 229 resident trout (6.8 pounds) were captured (Table 7). A DeLury estimate gives 102, 167, and 247,

TABLE 7.—*Brook trout taken from experimental area of East Lake Outlet by electrofishing*
[Parenthetical figures represent trout taken on first and second electrofishing, respectively]

Section	Domestic[1]	Wild	Resident	Total
1	17 (15 + 2)	18 (13 + 5)	23 (19 + 4)	58
2	13 (11 + 2)	21 (15 + 6)	23 (17 + 6)	57
3	15 (14 + 1)	16 (12 + 4)	34 (26 + 8)	65
4	15 (10 + 5)	10 (7 + 3)	29 (21 + 8)	54
5	11 (9 + 2)	17 (15 + 2)	38 (32 + 6)	66
6	12 (9 + 3)	18 (12 + 6)	23 (21 + 2)	53
7	8 (6 + 2)	20 (14 + 6)	29 (22 + 7)	57
8	3 (2 + 1)	24 (21 + 3)	30 (24 + 6)	57
Total	94	144	229	467

[1]Chi-square (domestic and wild) = 10.50, $P < 0.01$.

respectively, as the total population in the stream (Table 8). Of the 500 trout stocked from each group, these estimates represent survivals of 20 percent of the domestic and 33 percent of the wild trout. More wild trout than domestic fish survived in seven of the eight stream sections.

The nearly equal number of fish in each of the eight sections (60 to 70) attests to uniformity of habitat throughout the test area and efficiency of the electrofishing gear.

Wild fish greatly outnumbered the domestic in only the lowest two sections (Table 8). Water flow was considerably swifter and many pools were smaller in these two sections than the remainder of the stream. Exactly how swifter water influenced the two stocks was not determined.

TABLE 8.—*Population estimates (DeLury-type) for three groups of brook trout in East Lake Outlet experimental area*

Section	Domestic	Wild	Resident	Total
1	17	21	24	62
2	13	25	26	64
3	15	18	37	70
4	20	12	34	66
5	11	17	39	67
6	13	24	23	60
7	9	25	32	66
8	4	25	32	61
Total	102	167	247	516
Percentage of survival	20	33	—	—

Fish conditioned in a stream had better survival than fish reared in a hatchery pond (Miller, 1954). Needham and Slater (1945) had poor results with stream conditioning of fish but quoted H. S. Davis as having better survival with stream-conditioned rainbow trout. It is necessary, as Miller (1954) pointed out, for an introduced fish to find a suitable location before being overcome by exhaustion; otherwise it has to combat the current or other undesirable habitat. Thus, the wild stock with their greater stamina would have an advantage over the domestic fish. Increased stamina is certainly not the only factor aiding wild fish. As was evident in the laboratory tests, behavior differences might be detrimental or advantageous.

Better adaptation to higher temperature was given by Greene (1952) as one factor for higher survival of wild stock in Stillwater Pond, New York. Although the wild stock planted in East Lake Outlet could withstand higher water temperature, the creek temperature never approximated the lethal range.

FIGURE 9.—Wild (left) and domestic (right) fish after 73 days in East Lake Outlet.

Both groups planted in East Lake Outlet increased slightly in length. The mean length of the wild stock increased 0.48 inches, and the domestic, 0.34 inches (Table 9). As the wild fish were smaller when planted, their relative increase was greater than the actual increase suggests (Figure 9). Change in weight, an increase for the wild and decrease for the domestic, was slight for each group. This change is probably not enough to be important, but the total pounds planted and recovered shows a change. Approximately twice as many pounds of domestic fish were stocked,

but nearly equal poundage of the two stocks were recaptured. The condition factor[2] of both groups at time of capture was lower than when stocked and lower than that of the resident trout (Table 9).

Statistics of age distribution and size of the 229 resident trout are as follows:

Age	Number	Mean length (inches)	Total weight (pounds)
0+	76	2.1	0.30
I+	129	4.0	4.13
II+ (and older)	24	6.6	2.40

The resident fry were approximately 1 inch long at the time the test section was stocked. When captured at the end of the experiment, they had a mean length of 2.1 inches. Growth of the resident fry was greater than either of the planted groups.

Along with the resident population 1.1 pounds of stocked fish were recovered. As the area of the test section was approximately one-fourth acre, the standing crop at the end of the period was 30 pounds of fish per acre.

The first reaction of nearly all fish when put into the stream was to orient to the current, then move downward into a desirable water velocity. During this initial period the fish exhibited practically no fright from shadows or disturbances of the water. Frequently the introduced trout would move into a small hole or eddy with a resident fish.

About 10 percent of the domestic fish swam directly into a rock, sand bar, or even partially out of water, giving the impression that they were confused by their new surroundings. Several fish buried their heads in the soft sand by their aimless swimming. This was not observed in the wild stock. Behavior of this type is characteristic of fish that have been transported under adverse conditions where carbon dioxide is allowed to build up in the water. Accumulated metabolic wastes appeared to have greater effect upon domestic stock than wild stock. This agrees with earlier laboratory tests.

Downstream movement of fish out of the test area was slight. One wild, two domestic, and six resident trout were captured in the lower trap. The six resident fish were liberated below the test section, and the planted fish were returned upstream within the test area. A section of stream below the weir was electrofished to recheck on downstream movement, but only resident fish were recovered.

Laramie Pond

Laramie Pond provided an opportunity to investigate survival of test fish in a mitigated environment. This pond is in the northern Adirondack Mountains on the Brandon Preserve near Paul Smiths, New York. In 1957 a dam was constructed across a small tributary of the St. Regis River forming a pond with a surface area of approximately 0.5 acre and maximum depth of 8 feet. The temperature of the spring-fed inlet remains nearly

[2]Condition factor $= \frac{\text{Weight (pounds)} \times 100{,}000}{\text{Fork length}^3 \text{ (inches)}}$

TABLE 9. — *Growth of three stocks of fish after 73 days in East Lake Outlet*
[Standard deviations in parentheses]

Comparative factor	Item	Stock of fish		
		Domestic	Wild	Resident
Length	Mean length at stocking (inches)	2.41 (0.312)	2.04 (0.209)	
	Mean length at recapture (inches)	2.75 (0.372)	2.52 (0.303)	
	Length increase (inches)	0.34	0.48	
	Relative length increase (percentage)	14	23	
Weight	Number per pound at stocking	163	351	
	Number per pound at recapture	176	334	
	Weight change (number per pound)	−13	+17	
	Relative weight increase[1]			
Condition factor[2]	At stocking	44.85	33.50	
	At recapture	35.50	19.20	42.11

[1]Change was so slight it was considered insignificant.
[2]Based on mean weight and length.

constant at 48 to 52°F. Pond surface water temperature (1958) was 54°F. on June 16, rose gradually to 68°F. in mid-July, and cooled to 54°F. again by late September. On May 27, June 8, and July 14 a total of 1,500 pounds of agricultural lime was applied around the pond shore and at the inlet entrance. All fish in the watershed above the dam were eradicated by rotenone.

Movement of fish out of the pond was prevented by a screened box at the inlet and a Wolf-type fish trap at the spillway of the dam.

Six hundred and twenty-five fish from each of three different stocks were planted on June 16, 1958. The stocks were:

Stock	Mark	Total pounds
Domestic	RV	4.8
Wild	LV	2.2
Backcross	RP	2.0

Additional data are given in Table 11. The backcross were planted in connection with another project and consisted of a male "splake" (brook trout x lake trout hybrid) backcrossed to female brook trout.

Forty domestic, 13 wild, and 15 backcross trout were taken at the downstream trap and replaced in the pond. Eighteen of the domestic, eight of the wild, and three of the backcross moved downstream after August 19. Domestic male trout maturing at 0+ could account for the greater movement of domestic stock. However, movement of wild fish increased also during the same period even though they did not mature at this time.

The pond was drained and seined on October 2, 1958. Stragglers were recovered by DC electrofishing. For all practical purposes recovery was complete. Numbers of fish recovered were:

Stock	Number	Total pounds
Domestic	269	17.1
Wild	405	11.6
Backcross	388	11.8

Survival was 65 percent for the wild, 62 percent for the backcross, and 43 percent for the domestic.

The standing crop when the pond was drained was approximately 40 pounds of trout (80 pounds per acre). This was produced from 9.0 pounds of stocked fish.

Dead fish that collected at the downstream trap were counted each time the pond was visited (Table 10). The domestic fish had several periods of high mortality but never more than two wild or backcross fish were found dead at any one time. Highest mortality coincided with warmest water surface temperature. Some of the dead fish from each lot were gorged with maggots which came from fox carcasses suspended over the pond as a source of supplemental food. As domestic fish had mortality before maggots were available, it does not seem that they were the cause of a selective mortality.

Increase in length was comparable in all three groups (Table 11). Absolute increase in weight was more for the domestic stock, but as their weight at planting was greater the relative weight increase was similar for

FIGURE 10.—Wild (left) and domestic (right) fish after 103 days in Laramie Pond.

TABLE 10.—*Observed mortality in Laramie Pond*

Date	Water temperature (degrees F.)	Mortality		
		Domestic	Wild	Backcross
July 16	60	2	—	2
18	62	5	1	—
20[1]	—	9	—	1
23	64	1	—	2
25	—	—	—	1
29	65	6	2	1
30	66	3	—	—
31	64	2	2	—
August 1	66	6	2	—
3	68	15	2	—
19	68	4	—	1
22	66	12	2	2
25	66	1	—	—
27	64	4	—	1
29	66	2	—	2
September 2	62	—	1	—
4	62	6	2	—
Total		78	14	13

[1]Maggots were not available until after this date.

domestic and wild stocks (Figure 10). Wild stock was the only lot to have a lower condition factor at recapture than at planting.

Comparison of fish growth in Laramie Pond with fish growth from the same lots that remained in the hatchery should indicate adaptation to natural or to hatchery conditions. Wild fish that had been in Laramie Pond for the summer grew more than fish from the same lot that remained in the hatchery. (Laramie Pond wild fish had grown 1.0 inch more in mean length and 0.01 pound more in mean weight per fish than the hatchery fish.) Domestic fish grew nearly the same in both situations. (Laramie Pond domestic fish had grown 0.1 inch more in mean length and 0.01 pound less in mean weight than their hatchery counterparts.)

Twelve of 105 domestic fish recovered from Laramie Pond were mature males. The length of three males was less than the mean of 5.3 inches, and the remaining nine were longer. No wild or backcross stock was ripe. Cornell University personnel who have handled this domestic stock previously have noted that many males mature at 0+.

Fifty domestic and 50 wild fish were returned to the Cornell University Experimental Fish Hatchery. The domestic fish began feeding immediately and were not frightened by a hand placed in the trough nor by movements around the trough. The wild fish, on the other hand, did not begin feeding well for 4 days and after this time were easily frightened by the presence of a person or the feeding routine.

DISCUSSION

Throughout this study it has become evident that domestic and wild stocks of brook trout may differ in many ways and that these differences are, to a certain degree, genetical.

Genetical variations are difficult to assess. An individual fish is the culmination of interplay between the genes of the fish and the environment in which it is reared. In some situations genetical factors dominate, but in others environmental factors have their forte. Variable growth rates of different stocks of brook trout (Phillips *et al.*, 1957) and lake trout (Haskell, 1952) and the difference between stream and lake forms of brown trout (Alm, 1949) when reared under similar conditions illustrate genetical control. Environmental control is presented by Smith (1951) who found that sea-run brook trout could be recruited from trout that had not been to sea

TABLE 11.—*Growth of three stocks of fish after 108 days in Laramie Pond*
[Standard deviations in parentheses]

Comparative factor	Item	Stock of fish		
		Domestic	Wild	Backcross
Length	Mean length at stocking (inches)	2.7 (0.331)	2.1 (0.308)	2.2 (0.292)
	Mean length at recapture (inches)	5.3 (0.583)	4.6 (0.459)	4.3 (0.593)
	Length increase (inches)	2.6	2.5	2.1
	Relative length increase (percentage)	96	119	95
Weight	Mean weight at stocking (pounds)	0.008	0.004	0.003
	Mean weight at recapture (pounds)	0.064	0.028	0.030
	Weight increase (pounds)	0.056	0.024	0.027
	Relative weight increase (percentage)	731	700	838
Condition factor	At stocking	39.12	37.79	30.05
	At recapture	45.00	28.77	37.73

TABLE 12. — *Chemical composition of two lots of brook trout*
[Determinations were made on a wet and a dry basis and recorded as percentage]

Source	Length (inches)	Dry basis				Wet basis		
		Water	Ash	Fat	Protein	Ash	Fat	Protein
Hatchery domestic	5.2	68.7	7.6	21.9	58.9	2.4	6.8	18.4
Hatchery wild	3.7	75.7	8.9	18.8	60.9	2.2	4.6	14.8

for many generations and by Wilder (1952) in the similarity of anadromous and freshwater brook trout when reared together.

Morphological, physiological, behavioral, and genetical factors interact and mask specific cause and effect relations. Chain-like reactions can be triggered whereby a genetical change causes a behavioral change which in turn affects the physiology until finally a morphological change results.

Hatchery practices which continue for a long period may exert selective influence upon which fish are chosen for brood stock. The following three examples illustrate this point. (1) Hess (1935) found that a reduction of the Islets of Langerhans could be caused by a high fat diet, overeating, or lack of exercise. (2) Fish that remain near the surface of a raceway or trough have first choice of food, thus getting more as well as unleached food to eat. (3) Robust fish (high condition factor) are preferred by most hatchery managers even though a heavy-bodied fish appears to have no apparent survival advantage as shown by the wild stock planted in both East Lake Outlet and Laramie Pond. In the cases just mentioned, fish with characteristics that might be of doubtful survival value may be selected as brood stock.

Chemical composition was determined for a sample of domestic and wild-stock fish that had been reared together and fed the same diet (Table 12). The only significant difference is in the fat content, wild stock having less fat than the domestic fish. Phillips *et al.* (1955) found a similar situation with fat and ash content between hatchery-reared brook trout and wild brook trout. These fish, however, were from different bodies of water, and one group had a hatchery diet while the other had natural food. The differential utilization of the same food by the wild and domestic fish could be a basic underlying factor that attributes to other dissimilarities.

Selection rarely produces anything new but it does sort, isolate, recombine, and differentially preserve certain genetic traits. When the wide range of genetic preadaptness found in trout and the plasticity within this range are realized, selection becomes a powerful tool in the hands of the fish-culturist. On the other hand, the phenotypic selection usually practiced often has unknown influence through pleiotrophy and multiple factors upon the genotype. To maintain equilibrium, a change in any gene frequency or position by artificial selection requires a compensatory change in the frequency and position of other genes. By this means artificial selection for fast growth or early maturity can precipitate slight but insidious changes in behavior or physiology.

Selective breeding is often carried on in order to attain a specific body form, fast growth, and early maturity. The latter two are important in determining the first. Early maturity in many species is related to fast growth as was demonstrated by the Laramie Pond domestic trout. Time of sexual maturity (Alm, 1949; Brown, 1957) and growth rate (Haskell, 1952; Phillips *et al.*, 1957) are genetically controlled. The similar growth rate of test fish in both East Lake Outlet and Laramie Pond shows that under certain conditions wild stock can grow as rapidly as domestic. Environment, however, operates within the genetic framework. Slower growth rate of wild stock in a hatchery exemplifies this as well as Greene's (1955) transplanting of stunted brook trout. Sexual maturity can also act as an inhibitor of growth, especially in males (Graham, 1956; Brown, 1957; Hoar, 1957).

The dual effect of fast growth and early sexual maturity upon longevity has been discussed by several authors. McCay (1933) found that early-maturing, fast-growing rats have a shortened life span and concluded that "it is possible that longevity and rapid growth are incompatible." Ratcliff (1943), reporting on further work of McCay and others, said that fish and rats on a semi-starvation diet were stunted but longer-lived than their well-fed counterparts. Osborne *et al.* (1917) and

Zabinski (1929) suggested the possibility of prolonging the life of insects and rats by retarding growth. From the preceding statements it seems that fast growth and early maturity are frequently at the sacrifice of longevity. McCay (1952) and Comfort (1956) have examined this problem from a more general approach.

If Medawar's (1945) first law of growth (length), "size is a monotonic increasing function with age," is accepted as applying to fish, we can expect slow-growing, late-maturing individuals to attain a larger maximum size than those individuals that grow rapidly for a short period. Accelerated growth increases only the early growth and slows down the later, but retarded growth is just the opposite, often resulting in a larger individual (Hubbs, 1926).

Gerrish (1935) noted that few domestic trout lived over 4 years in England's streams, whereas natural fish may live twice as long. Greene (1952) found almost no survival of hatchery-strain brook trout after 3 years. In Wisconsin 95 percent of the male brook trout in St. Lawrence Creek mature at the end of their first summer and 85 percent of the females mature as yearlings (Brasch *et al.*, 1958). The same authors said that a Wisconsin brook trout over 3 years old is fairly rare. Presumably this included St. Lawrence Creek. Hatch (1959), working with the same stock of domestic brook trout as used in this present study, found few of them surviving more than 3 years in some of New York's Adirondack Mountain ponds. Brook trout stocked from hatcheries that bred for fast growth were shorter-lived than brook trout from hatcheries which obtained eggs from wild stock.

Not only is artificial selection operating, but also natural selection is absent. Many unfit are allowed to survive along with the fit. No premium is awarded for viability, stamina, wariness, or agility. Competition in a hatchery is greatly reduced allowing individuals to survive that would be eliminated in nature. These marginal individuals then contribute their genes to the population's progeny.

Since their origin each species of trout has evolved to fit a particular natural ecological situation. Fish-culturists, through artificial selection, are producing a fish adapted to a particular ecological situation, but it is a hatchery pond and not a stream or lake. When the environment suddenly changes, *i. e.* at planting, many of the adaptive advantages of artificial selection are not only of little or no value but may be detrimental.

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LITERATURE CITED

Alm, Gunnar. 1949. Influence of heredity and environment on various forms of trout. Rept. Inst. Freshwater Research, Drottningholm, 29: 29-34.

Black, Edgar C. 1957. Alternations in the blood level of lactic acid in certain salmonoid fishes following muscular activity. I. Kamloops trout, *Salmo gairdneri*. Jour. Fish. Res. Bd. Canada, 14 (2): 117-134.

Brasch, John, James McFadden, and Stanley Kmiotek. 1958. The eastern brook trout, its life history, ecology, and management. Wisconsin Cons. Dept. Publ. 226, 11 pp.

Brett, J. R., M. Hollands, and D. F. Alderdice. 1958. The effect of temperature on the cruising speed of young sockeye and coho salmon. Jour. Fish. Res. Bd. Canada, 15 (4): 587-605.

Brown, M. E. 1957. Experimental studies on growth. *In:* The physiology of fishes, Vol. 1: Metabolism, ed. M. E. Brown. Academic Press, New York. pp. 361-400.

Comfort, Alex. 1956. The biology of senescence. Routledge and Kegan Paul, London. 257 pp.

DeLury, D. B. 1947. On the estimation of biological populations. Biometrics, 3 (4): 145-167.

Eipper, Alfred W. 1953. The effect of hatchery growth rate on the survival of brown trout planted in Fall Creek, New York. Doctoral Thesis, Cornell University. 151 pp.

Embody, G. C. 1921. Concerning high water temperatures and trout. Trans. Am. Fish. Soc., 51: 58-64.

Fry, F. E. J. and J. S. Hart. 1948. Cruising speed of goldfish in relation to water temperature. Jour. Fish. Res. Bd. Canada, 7 (4): 169-175.

Gerrish, C. S. 1935. Are farm fish short lived? Salmon and Trout Mag., 81: 331-344.

GRAHAM, J. J. 1956. Observations on the alewife, *Pomolobus pseudoharengus* (Wilson) in fresh water. Univ. of Toronto Stud., Biol. Ser. 62, Publ. Ont. Fish. Res. Lab., 74, 48 pp.

GRAY, JAMES. 1957. How fishes swim. Sci. Am., 197 (2): 48-54.

GREENE, A. F. C. 1955. Will stunted brook trout grow? Prog. Fish-Cult., 17 (2): 91.

GREENE, C. WILLARD. 1952. Results from stocking brook trout of wild and hatchery strains at Stillwater Pond. Trans. Am. Fish. Soc., 81: 43-52.

GUNTER, GORDON. 1947. Differential rate of death for large and small fishes caused by hard cold waves. Science, 106 (2579): 472.

HASKELL, DAVID C. 1952. Comparison of the growth of lake trout fingerlings from eggs taken in Seneca, Saranac, and Raquette Lakes. Prog. Fish-Cult., 14 (1): 15-18.

HATCH, R. W. 1959. Trout production in four Adirondack ponds. Doctoral Thesis, Cornell University. 220 pp. (In press).

HESS, W. N. 1935. Reduction of the Islets of Langerhans in the pancreas of fish by means of diet, overeating, and lack of exercise. Jour. Exp. Zool., 70 (2): 187-194.

HOAR, W. S. 1957. The gonads and reproduction. *In*: The physiology of fishes, Vol. 1: Metabolism, ed. M. E. Brown. Academic Press, New York. pp. 287-321.

HOAR, WILLIAM S. and MERVA K. COTTLE. 1952. Dietary fat and temperature tolerance of goldfish. Can. Jour. Zool., 30 (1): 41-48.

HUBBS, CARL L. 1926. The structural consequences of modifications of the development rate in fishes, considered in reference to certain problems of evolution. Am. Naturalist, 60: 57-81.

HUNTSMAN, A. G. 1942. Death of salmon and trout with high temperature. Jour. Fish. Res. Bd. Canada, 5 (5): 485-501.

. 1946. Heat stroke in Canadian Maritime stream fishes. Jour. Fish. Res. Bd. Canada, 6 (7): 476-482.

JONES, F. R. HARDEN. 1957. The swim bladder. *In*: The physiology of fishes, Vol. II: Behavior, ed. M. E. Brown. Academic Press, New York. pp. 305-322.

KEYS, ANCEL B. 1931. A study of the selective action of decreased salinity and of asphyxiation on the Pacific killifish, *Fundulus parvipinnis*. Bull. Scripps Inst. Oceanogr., Tech. Ser., 2 (12): 417-490.

MARTIN, W. R. 1949. The mechanics of environmental control of body form in fishes. Univ. Toronto Stud., Biol. Ser. 58, Publ. Ont. Fish. Res. Lab., 70: 58-81.

MCCAY, C. M. 1933. Is longevity compatible with optimum growth? Science, 77 (2000): 410-411.

———. 1952. Problems of ageing. ed. Albert I. Lansing. Williams and Wilkins Co., Baltimore. pp. 139-202.

MEDAWAR, P. B. 1945. Essays on growth and form. Oxford Univ. Press, London & New York. pp. 157-187.

MILLER, RICHARD B. 1954. Comparative survival of wild and hatchery-reared cutthroat trout in a stream. Trans. Am. Fish. Soc., 83: 120-130.

———. 1957. Permanence and size of home territory in stream-dwelling cutthroat trout. Jour. Fish. Res. Bd. Canada, 14 (5): 687-691.

———. 1958. The role of competition in the mortality of hatchery trout. Jour. Fish. Res. Bd. Canada, 15 (1): 27-45.

NEEDHAM, PAUL R. 1949. Survival of trout in streams. Trans. Am. Fish. Soc., 77: 26-31.

NEEDHAM, PAUL R. AND DANIEL W. SLATER. 1944. Survival of hatchery-reared brown and rainbow trout as affected by wild trout populations. Jour. Wildl. Mgt., 8 (1): 22-36.

———. 1945. Seasonal changes in growth, mortality, and condition of rainbow trout following planting. Trans. Am. Fish. Soc., 73: 117-124.

NIELSON, R. S., N. REIMERS, AND H. D. KENNEDY. 1957. A six-year study of the survival and vitality of hatchery-reared rainbow trout of catchable size in Convict Creek, California. Calif. Fish and Game, 43 (1): 5-42.

OSBORNE, T. B., L. B. MENDEL, AND E. L. FERRY. 1917. The effect of retardation of growth upon the breeding period and duration of life of rats. Science, 45 (1160): 294.

PHILLIPS, ARTHUR M. JR., FLOYD E. LOVELACE, HENRY A. PODOLIAK, DONALD R. BROCKWAY, AND GEORGE C. BALZER JR. 1955. N. Y. Cons. Dept., Cortland Hatchery Report 24, Fish. Res. Bull. 19: 37-42.

PHILLIPS, ARTHUR M. JR., HENRY PODOLIAK, DONALD R. BROCKWAY, AND RAY R. VAUGHN. 1957. N. Y. Cons. Dept., Cortland Hatchery Report 26, Fish. Res. Bull. 21: 88-89.

RADCLIFFE, ROLAND W. 1950. The effect of finclipping on the cruising speed of goldfish and coho salmon fry. Jour. Fish. Res. Bd. Canada, 8 (2): 67-73.

RATCLIFF, J. D. 1943. Let's live a little longer. Colliers, Mar. 13, 1943, pp. 11, 72.

REIMERS, NORMAN. 1956. Trout stamina. Prog. Fish-Cult., 18 (3): 112.

SCHUCK, HOWARD A. 1948. Survival of hatchery trout in streams and possible methods of improving the quality of hatchery trout. Prog. Fish-Cult., 10 (1): 3-14.

SCHUCK, HOWARD A. AND O. R. KINGSBURY. 1948. Survival and growth of fingerling brown trout *(Salmo fario)* reared under different hatchery conditions and planted in fast and slow water. Trans. Am. Fish. Soc., 75: 147-156.

SMITH, M. W. 1951. The speckled trout fishery of Prince Edward Island. Can. Fish Cult., No. 11: 1-6.

Smith, S. B. 1957. Survival and growth of wild and hatchery rainbow trout in Corbett Lake, British Columbia. Can. Fish Cult., No. 20: 7-12.

Stone, Livingston. 1873. Domesticated trout. Office of the Fishing Gazette, London. 367 pp.

Tester, A. L. 1937. Populations of herring *(Clupea pallasii)* in the coastal waters of British Columbia. Jour. Biol. Bd. Canada, 3 (2) : 108-144.

Threinen, C. W. 1958. Cause of mortality of a midsummer plant of rainbow trout in a southern Wisconsin lake, with notes on acclimation and lethal temperatures. Prog. Fish-Cult., 20 (1) : 27-32.

Vibert, Richard. 1956. Methode pour l'étude et l'amélioration de la survie des alevins de repeuplement. Annales de la Station Centrale d'Hydrobiologie appliquée, 6: 348-439.

Wales, J. H. 1954. Relative survival of hatchery and wild trout. Prog. Fish-Cult., 16 (3) : 125-127.

Webster, Dwight A. 1951. Fishery survey of certain waters of the Adirondack League Club Preserve, II: First Bisby Lake, Chamber's Lake, Sylvan Ponds, Honnedaga and Baby Lake. Adirondack League Club. 40 pp. (Mimeo.).

———. 1954. A survival experiment and an example of selective sampling of brook trout *(Salvelinus fontinalis)* by angling and rotenone in an Adirondack pond. N. Y. Fish and Game Jour., 1 (2) : 214-219.

———. 1957. Fisheries management report for 1956. Adirondack League Club. 26 pp. (Mimeo.).

Wilder, D. G. 1952. A comparative study of anadromous and freshwater populations of brook trout. Jour. Fish. Res. Bd. Canada, 9 (4) : 169-203.

Zabinski, J. 1929. The growth of blackbeetles and of cockroaches on artificial and incomplete diets. Part I. Jour. Exp. Biol., 6: 360-385.

Confidence Limits Associated with Means and Medians of Series of Net Catches

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ABSTRACT

Statistical methods for determining errors associated with means and medians of series of catches in stationary nets are discussed and two suggested methods presented: a parametric method based on the negative binomial distribution and a non-parametric method using sequential ranking of values around the median. It is concluded that the former is most useful from the viewpoint of mathematical description, and the latter is of greatest value where the number of net sets is small and fish of a particular kind are taken in most of the sets.

INTRODUCTION

Averages, especially means or common averages, of series of catches of gill nets or trap nets that have been fished for a standard length of time, have often been used as indications of fish abundance. This approach is based upon the reasonable assumption that the more fish present in a lake, of a size large enough to be taken, the greater the average catch per net is apt to be. Passive-fishing nets are, of course, selective, and some kinds of fish are more readily taken than others. Because of this, comparison of catches from any kind of passive-fishing gear should be made by species.

From the series of gill-net catches presented by Moyle (1949) and from other catch data from Minnesota lakes, it is apparent that the catches (numbers of fish) of a series of gill nets have the following statistical attributes: (1) a standard deviation that is usually about the size of the mean; and (2) a distribution curve of the catches that is usually positively skewed, indicating more catches below the mean of the series than above it. This skewness is probably related to behavior patterns of the fish, such as schooling and feeding habits, and to non-uniformity of habitats netted. Because of skewed distribution of the catches, use of the usual methods of "normal" statistics for determination of statistical error and confidence limits associated with the mean is not valid, and is apt to lead to erroneous conclusions.

After trying several statistical approaches, including that of the Poisson distribution, two methods have been found that show promise for estimating sampling error of netting. These are: (1) a parametric approach, using methods applicable to the negative binomial distribution; and (2) a non-parametric method using the median as an "average" and in which no assumption is made as to the form of the distribution of the net catches.

Although catches from a series of gill nets often approximate a Poisson distribution, there are difficulties which preclude this statistical approach. A Poisson distribution can be assumed only: (1) if individual animals (such as fish) are randomly distributed throughout a medium (such as a lake); and (2) if the volume or space occupied by the animals is small compared to the total volume of the habitat. Under such conditions there will be many units of space in the lake without fish and from which no fish can be taken by nets; but there will be an equal chance that any space may contain one or more fish that can be taken. It is a matter of common fisheries knowledge, however, that fish are not randomly distributed in a lake and that grouping of them may occur because of social and feeding habits, and because the lake habitat is not uniform. Also the catch, or sampling, of fish populations by gill nets depends on movement of the fish, thus introducing another variable.

USE OF THE NEGATIVE BINOMIAL DISTRIBUTION

Several authors, especially Anscombe (1949) and Fisher *et al.* (1943), have suggested application of statistical methods that stem from the negative binomial distribution to such irregularly distributed material. Kut-

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kuhn (1958) applied this approach to counts of certain plankton organisms in a lake.

The negative binomial distribution is related to and derived from a Poisson distribution which has a parameter that is in itself a variable and is distributed similarly to a chi-square distribution, and as will be shown, the shape of the curve obtained empirically by plotting net catches is similar to that formed by a negative binomial distribution. Since the latter has a sound mathematical basis, it is possible to use it for determining confidence limits.

The form of the negative binomial distribution (that is, shape of the curve formed by such a distribution) can be expressed mathematically as:

$$F(x) = \frac{(K+x-1)!}{x!(K-1)!}\left(\frac{M}{M+K}\right)^{x}\left(\frac{M+K}{K}\right)^{-K}$$

Where: x=any value of the variable (such as number of fish per net lift)

F(x)=any point on the curve representing a probability of occurrence of a value of x

M=the true population mean; a parameter, of which a sample mean is an estimate

K=a constant for any particular distribution that is related to both the mean (M) and the variance σ^2 by the formula:

$$K = \frac{M^2}{\sigma^2 - M}$$

Decrease in the value of the reciprocal of K indicates decreased dispersion of the series and as dispersion decreases the value of σ^2 approaches M and the shape of the distribution approaches that of a Poisson series in which the variance equals the mean. The quantity 1/K is here called the "dispersion index." From the present point of view the most useful feature of the negative binomial distribution is, that by a transformation of the type $y_i = \log (x_i + \hat{K}/2)$ the data are transformed to a variable having approximately a normal distribution and therefore can be used for determining confidence limits. In the foregoing formula, the x_i values represent the original catch values and $\hat{K}$ is an estimate of the parameter K already described.

In Table 1 several observed distributions of gill-net and trap-net catches are compared with negative binomial distributions as calculated using the netting data. It will be seen

TABLE 1.—*Negative binomial distribution fitted to distribution of catches in 10 series of gill-net and trap-net sets*

[Asterisk indicates total for all categories of higher value]

Species	Lake	Total number of sets		Number of sets containing specified numbers of fish											$1/\hat{K}$	Chi-square	Degrees of freedom[2]
				0	1	2	3	4	5	6	7	8	9	10+			
Northern pike	Minnewaska	30	observed	12	10	6	1	1							.385	1.1243	1
			expected	13.9	9.3	4.3	1.7	.8*									
Northern pike	Forest	15	observed	5	5	3	0	1	1						.562	.2354	1
			expected	5.6	4.2	2.5	2.7*										
Northern pike	Kabetogama	18	observed	10	3	2	2	1							.862	.8468	1
			expected	9.1	4.7	2.2	1.1	.9*									
Walleye	Cass	30	observed	2	4	3	2	2	1	1	3	3	1	8	1.198	2.8749	2
			expected	4.4	3.3	2.7	2.3	2.0	1.8	1.6	1.4	1.2	1.1	8.2*			
Walleye	Minnewaska	30	observed	4	3	7	3	2	3	4	3	1			.204	3.5287	3
			expected	2.3	4.6	5.5	5.2	4.2	3.1	1.4	3.7*						
Walleye	Forest	15	observed	3	7	1	2			2					.556	.6924	1
			expected	4.3	3.9	2.7	1.7	2.4*									
Northern pike	Pelican	15	observed	4	5	2	2	1		1					.455	.50478	2
			expected	4.3	4.2	2.9	1.7	1.9*									
Perch[1]	Clear	56	observed	27	5	4	9	0	1	4	2	3	1		1.235	16.89	3
			expected	20	11.4	7.4	5.0	3.4	2.4	1.7	1.1	3.6*					
Bullhead[1]	Ball Club	29	observed	6	9	4	4		1		1		1	3	1.923	8.54	2
			expected	10.2	4.6	3.0	2.2	1.7	7.3*								
Green sunfish[1]	Ham	88	observed	26	22	14	7	2	4	5	3	1	1	3	1.149	4.7142	4
			expected	28.4	18.0	12.2	8.5	6.0	4.2	3.0	2.2	1.6	1.1	2.8*			

[1]Trap nets.
[2]Degrees of freedom = N-2.

that the observed and calculated values for distribution of net catches with means of several sizes are usually close. This agreement is also indicated by low chi-square values obtained when the two distributions are compared. Of the 10 series of catches, only in the catch data for perch taken in trap nets from Clear Lake (chi square, 16.89), and for bullheads taken in trap nets from Ball Club Lake (chi square, 8.54) are there significant differences between the observed and calculated distributions at the 95 percent probability level.

For the catches in Table 1, the dispersion index, $(1/\hat{K})$ of trap-net catches of bullheads and green sunfish is between 1 and 2, and for the gill-net catches of northern pike and walleyes it is usually less than 1, thus indicating less dispersion around gill-net catch means for the species considered.

Distribution of trap-net catches of perch from Clear Lake, which ranged from zero to nine per lift, do not fit the negative binomial distribution too well, but it is evident that no other unimodal curve can be expected to give a much better fit.

Confidence limits at the 80 percent probability level associated with means of 1.0, 5.0, and 10.0 of negative binomial distributions with $1/K = 0.5$, 0.2, and 0.1, and for several sample sizes are shown in Tables 2 and 3. It will be seen from these tables that the error associated with means of such series at the 80 percent probability level is large and that, as Moyle (1949) earlier concluded from an empirical approach, the 80 percent probability level is about as high a statistical accuracy as can be achieved in practical fish-population sampling by use of passive-fishing nets in lakes.

TABLE 2.—*Eighty percent confidence limits for a mean value of 1 fish per net and four values of the dispersion index, (1/K); negative binomial distribution*

Number of sets	1/K = 1	1/K = 0.5	1/K = 0.2	1/K = 0.1
2	.19 - 3.00	.19 - 2.42	.19 - 2.10	.19 - 2.00
3	.34 - 2.63	.34 - 2.16	.34 - 1.90	.34 - 1.81
4	.42 - 2.42	.42 - 2.01	.42 - 1.78	.42 - 1.71
5	.49 - 2.27	.49 - 1.90	.49 - 1.70	.49 - 1.63
6	.53 - 2.16	.53 - 1.82	.53 - 1.64	.53 - 1.58
7	.57 - 2.07	.57 - 1.76	.57 - 1.59	.57 - 1.53
8	.59 - 2.00	.59 - 1.71	.59 - 1.55	.59 - 1.50
9	.62 - 1.94	.62 - 1.67	.62 - 1.52	.62 - 1.47
10	.64 - 1.89	.64 - 1.64	.64 - 1.49	.64 - 1.45
12	.67 - 1.82	.67 - 1.58	.67 - 1.45	.67 - 1.41
15	.70 - 1.73	.70 - 1.52	.70 - 1.40	.70 - 1.36
20	.74 - 1.63	.74 - 1.45	.74 - 1.35	.74 - 1.32
30	.79 - 1.52	.79 - 1.37	.79 - 1.28	.79 - 1.26
40	.82 - 1.45	.82 - 1.32	.82 - 1.25	.82 - 1.22
50	.84 - 1.40	.84 - 1.28	.84 - 1.22	.84 - 1.20

Problem. — As an example of the application of the foregoing approach for determination of reliability of means of netting data, the following problem is presented. Ten gill-net sets are made in a lake in year A. The numbers of walleyes taken in each set are 1, 2, 4, 6, 9, 10, 11, 14, 16, 27. The mean catch, standard deviation, and dispersion factor $(1/\hat{K})$ are calculated. The mean is 10 fish per set, and $1/\hat{K}$, the dispersion factor, is 0.5. The following year, year B, at about the same date, 8 gill-net sets are made, and the numbers of walleyes taken per set are 0, 0, 1, 1, 6, 6, 12, 14. The catch mean is found to be 5 fish with $1/\hat{K}$ equal to 1.0. The question is: do the means of the walleye catches in years A and B represent catch parameters that can be considered different at the 80 percent probability level.

TABLE 3.—*Eighty percent confidence limits for mean values of 5 and 10 fish per net and four values of the dispersion index, (1/K); negative binomial distribution*

	Mean = 5				Mean = 10			
Number of sets	1/K = 1	1/K = 0.5	1/K = 0.2	1/K = 0.1	1/K = 1	1/K = 0.5	1/K = 0.2	1/K = 0.1
2	1.77 - 14.43	2.14 - 10.48	2.59 - 8.55	2.80 - 7.82	3.14 - 29.83	4.25 - 22.06	5.72 - 16.51	6.55 - 14.48
3	1.93 - 11.64	2.53 - 9.19	2.96 - 7.80	3.16 - 7.25	3.92 - 24.46	5.01 - 19.13	6.38 - 15.10	7.12 - 13.57
4	2.22 - 10.64	2.79 - 8.49	3.20 - 7.37	3.39 - 6.92	4.46 - 21.73	5.52 - 17.56	6.80 - 14.31	7.47 - 13.05
5	2.43 - 9.84	2.98 - 8.05	3.37 - 7.09	3.55 - 6.70	4.86 - 20.04	5.89 - 16.57	7.09 - 13.79	7.71 - 12.70
6	2.59 - 9.29	3.13 - 7.73	3.49 - 6.89	3.66 - 6.54	5.19 - 18.87	6.18 - 15.86	7.31 - 13.42	7.90 - 12.44
7	2.73 - 8.88	3.24 - 7.49	3.59 - 6.73	3.76 - 6.42	5.46 - 18.01	6.41 - 15.34	7.50 - 13.14	8.04 - 12.25
8	2.84 - 8.56	3.34 - 7.30	3.68 - 6.61	3.83 - 6.32	5.68 - 17.35	6.60 - 14.93	7.64 - 12.91	8.16 - 12.09
9	2.94 - 8.31	3.42 - 7.15	3.74 - 6.51	3.89 - 6.24	5.87 - 16.81	6.76 - 14.59	7.76 - 12.73	8.26 - 11.97
10	3.02 - 8.10	3.49 - 7.02	3.80 - 6.42	3.95 - 6.18	6.03 - 16.37	6.90 - 14.32	7.87 - 12.58	8.34 - 11.86
12	3.16 - 7.77	3.60 - 6.82	3.90 - 6.29	4.04 - 6.07	6.31 - 15.69	7.13 - 13.88	8.03 - 12.33	8.48 - 11.69
15	3.32 - 7.42	3.73 - 6.60	4.01 - 6.14	4.13 - 5.95	6.63 - 14.97	7.40 - 13.41	8.23 - 12.07	8.63 - 11.50
20	3.51 - 7.04	3.89 - 6.38	4.13 - 5.98	4.24 - 5.82	7.01 - 14.19	7.71 - 12.90	8.45 - 11.77	8.81 - 11.29
30	3.75 - 6.62	4.07 - 6.09	4.28 - 5.79	4.38 - 5.66	7.48 - 13.31	8.09 - 12.31	8.72 - 11.53	9.02 - 11.05
40	3.90 - 6.38	4.19 - 5.94	4.38 - 5.68	4.46 - 5.57	7.78 - 12.81	8.32 - 11.98	8.88 - 11.23	9.15 - 10.90
50	4.00 - 6.22	4.27 - 5.83	4.44 - 5.61	4.52 - 5.51	7.99 - 12.48	8.49 - 11.75	9.00 - 11.09	9.24 - 10.81

Solution. — It will be observed, from the theoretical distribution of error at the 80 percent probability level shown in Table 3, that the range of error associated with a mean of 10 fish from 10 sets, with 1/K equal to 0.5, is 6.9 to 14.3 fish. Similarly the range of error associated with the mean of five fish from eight sets, at 1/K equal to 1.0, is 2.8 to 8.6. Since the two ranges overlap, it cannot be assumed, on the basis of a comparison of this kind, that the chances are four out of five that the two catch means represent different catch parameters. It must be pointed out, however, that such comparison of confidence limits is a conservative test. If the two ranges did not overlap, the probability would be much higher than the indicated 80 percent that the two means represent different populations. In order to test these two series more accurately it is necessary to apply the conversion formula, $y_i = \log (x_i + \hat{K}/2)$, to both sets of data and then apply the standard t test for the difference between means of normally distributed populations. When this is done, in this case the value of t is 2.117 or a value that has a probability of occurrence of .05, that is, means coming from two equal population values as extreme as these could be expected to occur only five times out of 100. This illustrates that direct comparison of confidence limits is too conservative to be used as an exact test of equality.[2]

USE OF NON-PARAMETRIC METHODS

The second proposed method for evaluation of catch averages of a series of nets is based on non-parametric methods and makes use of the median rather than the mean of the series. In skewed series the median is generally more descriptive of average conditions than is the mean. Confidence limits associated with the median can be determined by the method of Mood (1950). Briefly this method is: the sample, such as catches of a series of nets, is arranged in ascending numerical order: x_1, x_2, x_3, ... x_n, with x_n being the largest observation in a sample of size n. The median is determined by selecting the value of the central term in odd-numbered series or a common average of the two central terms in even-numbered series. The probability that any observation will fall either to the right or left of V, the true median of the population in an infinite theoretical series, is 1/2, and the probability that i observations (any sequential number of items starting with x_i in the series) falling to the left of the median (V) is:

$$\frac{n!}{i!(n-i)!}\left(\frac{1}{2}\right)^n$$

By computing probabilities associated with various values of n (number of net sets, for example) approximate confidence intervals for V (the true median) can be determined. In Table 4 calculated confidence limits associated with samples of several sizes (based on a binomial distribution) are given. It should be noted that by this method confidence limits are a function of sample size and must be determined separately for each series of observations considered.

The equality of medians from two independent samples (such as series of net catches) can be compared by using the median test of Siegel (1956, pp. 111-116). When the two samples (Samples I and II) are to be compared, these are combined and the common median of the combined series determined. The items in the two original

[2]Another transformation that could be used is $y_i = \sqrt{x_i + .5}$. Strictly speaking, this is applicable only to data having a Poisson distribution. Using it in this case yields a t value of 1.710 which has a probability of occurrence of 0.11. The error then is on the conservative side, but the relative ease of computation may make this transformation more desirable on occasion than the logarithmic.

TABLE 4.—*Confidence intervals for median values (V) for various sample sizes based on binomial distribution of values*

[Pf = fiducial probability]

Sample size	Confidence intervals		
6	Pf ($x_1 < V < x_6$) = .97	Pf ($x_2 < V < x_5$) = .78	
7	Pf ($x_1 < V < x_7$) = .98	Pf ($x_2 < V < x_6$) = .88	Pf ($x_3 < V < x_5$) = .55
8	Pf ($x_1 < V < x_8$) = .99	Pf ($x_2 < V < x_7$) = .93	Pf ($x_3 < V < x_6$) = .71
9	Pf ($x_1 < V < x_9$) = .996	Pf ($x_2 < V < x_8$) = .96	Pf ($x_3 < V < x_7$) = .82
10	Pf ($x_2 < V < x_9$) = .98	Pf ($x_3 < V < x_8$) = .89	Pf ($x_4 < V < x_7$) = .66
11	Pf ($x_2 < V < x_{10}$) = .99	Pf ($x_3 < V < x_9$) = .93	Pf ($x_4 < V < x_8$) = .77
12	Pf ($x_2 < V < x_{11}$) = .99	Pf ($x_3 < V < x_{10}$) = .96	Pf ($x_4 < V < x_9$) = .85
13	Pf ($x_3 < V < x_{11}$) = .98	Pf ($x_4 < V < x_{10}$) = .91	Pf ($x_5 < V < x_9$) = .73
14	Pf ($x_4 < V < x_{11}$) = .94	Pf ($x_5 < V < x_{10}$) = .82	Pf ($x_6 < V < x_9$) = .58
15	Pf ($x_4 < V < x_{12}$) = .96	Pf ($x_5 < V < x_{11}$) = .88	Pf ($x_6 < V < x_{10}$) = .70

samples are then arranged in a 2 by 2 table as follows:

	Number of items in sample series	
	Below common median	Above common median
Sample I		
Sample II		

The probability that a given number of items will be above or below the common median can then be determined by the Chi-square Test or Fischer's Exact Probability Test (Siegel, 1956, pp. 96-104).

If it is desired to compare a sample median with a true, or assumed true, median value (such as a state-wide gill-net catch median), the method used is similar to that just described for determination of confidence limits. The true median used is considered to be the real or true median of the sample and the numbers of items below and above it in the sample are determined. In Table 5 calculated fiducial probabilities associated with medians of a theoretical series based on binomial distribution are given.

As an example of the use of this method, let us consider the catch of a particular kind of fish in two series of gill-net lifts each from a different lake: S_1 in which seven sets were made, and S_2 in which nine sets were made. It is wished to compare the validity of the medians from these two series and to compare each with the state-wide catch median (V) for this species. The catch, as numbers of fish per net, for the individual nets of the two series is:

$S_1 = 0, 0, 1, 2, 3, 3, 4$
$S_2 = 2, 4, 4, 5, 6, 6, 8, 9, 11$
$V = 7$ (state-wide catch median)

For S_1, which is a series of seven items, the median is 2 and from Table 4 (third column, second item) it will be observed that x_2 and x_6 observations in a series of seven items delimit the median at 88 percent confidence. In the S_1 series x_2 and x_6 represent a range of zero to three fish per net. For S_2, which is a series of nine items, the median is 6 and the range (x_3 to x_7) at 82 percent confidence limits is 4 to 8. Since the confidence limits do not overlap we can assume that the two catch series represent different parameters at a probability greater than four chances out of five. For more exact comparison of the two samples the catches can be combined into a single series that has a common median of 4. A 2 by 2 table is then prepared as follows:

	Number of items in sample series		
	Below common median	Above common median	Totals
Sample I (S_1)	7	0	7
Sample II (S_2)	3	6	9
Totals	10	6	16

It should be noted that in both samples there are observations that are equal to the common median and in such cases the sample is divided into observations *less than or equal to* the common median, and samples *greater than* the common median.

If both samples are considered to represent catch series from a parent population having the median 4, the number of observations below this median for S_1 could be expected to be 4.4, with 2.6 above the median. Similarly the expected distributions for S_2 are 5.6 above and 3.4 below the common median. Since the expected numbers in all four cases do not exceed 5, the Chi-square Test cannot be used; but use of Fischer's Exact Probability Test (Siegel, 1956) gives a value of 0.0104 and indicates that the probability of these two samples coming from the same population is about 1 in 100.

When the median and range of the two samples, S_1 and S_2, are compared with the state-wide median of 7 it will be seen that the range of S_1 (0-4) does not include the state-wide median. In this case it can safely be assumed that the median of S_1 represents a parameter different from that of which the state-wide median is representative. In S_2, which has a median of 6, the state-wide median of 7 falls between items x_6 and x_7 of the series (between 6 and 8 fish). From Table 5, which presents fiducial probabilities based on a binomial distribution, it will be seen that the chances that the true median *(V)* of the population which S_2 represents will be greater than x_6 is 0.25. (Read down in Column 1 of Table 5 to "9" (sets) and count across to the sixth *i* column).

There is, then, in this case, one chance in four (probability 0.25) that S_2, with a median of six fish, comes from a population that is represented by a true median of seven fish or greater. Conversely, there are three chances out of four (1 minus .25) that the true median of the population which S_2 represents is less than seven.

DISCUSSION

The parametric method described, based on the negative binomial distribution, can be used to assign confidence limits to means of net catches but appears to be most useful from the viewpoint of mathematical description, especially since the mean is often considered to be the best single statistic for describing a population, and is most generally understood. The dispersion index, $1/\hat{K}$, associated with this distribution promises to be useful for comparison of catch efficiency of gear and estimating amount of association in populations of different kinds of fishes.

The non-parametric method described, based on the median, appears to be most useful for evaluating and comparing catches of nets where: (1) the number of net sets (sample size) is small; and (2) fish of a particular species are taken in most of the sets. The median is much less sensitive to extreme observations (such as large infrequent catches of individual nets) than is the mean, and therefore can be expected to have a narrower range of error associated with it at any probability level. By use of the non-parametric (median) method described, it is quite easy to make probability statements concerning the difference between two medians, or between a sample median and a true (or assumed true) population median used for comparison.

In recording averages of series of net catches it seems desirable to include both the mean and the median. Although the median appears most useful for evaluating catches, it has the important disadvantage of being zero if more than half the nets in a sample series do not take fish of the kind considered, an obvious mathematical understatement.

LITERATURE CITED

Anscombe, F. J. 1949. The statistical analysis of insect counts based on the negative binomial distribution. Biometrics, 5: 165-173.

Fisher, R. A., A. S. Corbett, and C. B. Williams. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. Jour. Animal Ecol., 12: 42-58.

Kutkuhn, J. H. 1958. Notes on the precision of numerical and volumetric plankton estimates from small-sample concentrates. Limnol. and Oceanogr., 3 (1): 69-83.

Mood, A. M. 1950. Introduction to the Theory of Statistics. McGraw-Hill Book Co., New York. xii + 433 pp.

Moyle, J. B. 1949. Gill nets for sampling fish populations in Minnesota waters. Trans. Am. Fish. Soc., 79: 195-204.

Siegel, S. 1956. Non-Parametric Statistics. McGraw-Hill Book Co., New York. xiii + 312 pp.

Table 5.—*Table of probabilities for comparison of state-wide median net catches with medians of any sample series*

[The fiducial probability that in a sample of N observations, the true median, of which the sample median is an estimate, will be greater than the observed numerical value of the i-th ordered observation. N is the number of observations, such as the number of net sets; i is the sequential position of any observation (such as number of fish per set) in the sample series when the series is arranged in the order of ascending numerical value.]

N	Probability															
1	.50															
2	.75	.25														
3	.93	.50	.13													
4	.94	.69	.31	.06												
5	.97	.81	.50	.19	.03											
6	.98	.88	.66	.34	.12	.02										
7	.99	.94	.77	.50	.23	.06	.01									
8	1.0	.97	.86	.64	.36	.14	.04	*								
9	1.0	.98	.91	.75	.50	.25	.09	.02	*							
10	1.0	.99	.95	.83	.62	.38	.17	.05	.01	*						
11	1.0	.99	.97	.89	.73	.50	.27	.11	.03	.01	*					
12	1.0	1.0	.98	.93	.81	.61	.39	.19	.07	.02	*	*				
13	1.0	1.0	.99	.95	.87	.71	.50	.29	.13	.05	.01	*	*			
14	1.0	1.0	.99	.97	.91	.79	.60	.40	.21	.09	.03	.01	*	*		
15	1.0	1.0	1.0	.98	.94	.85	.70	.50	.30	.15	.06	.02	*	*	*	
16	1.0	1.0	1.0	.99	.96	.89	.77	.60	.40	.23	.11	.04	.01	*	*	*
i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

*—less than .01

Experimental Improvement of a Bulldozed Trout Stream in Northern Maine

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ABSTRACT

Brook-trout habitat in Big Hudson Brook was destroyed in 1950 by extensive bulldozing in preparation for pulpwood driving. Following bulldozing, the brook had no well-defined channel at low water levels, water temperatures reached the mid-seventies, and the small flow seeped through bottom rubble. Although restoration of original habitat conditions was impossible, an attempt was made, using a bulldozer, to improve trout-stream habitat that had been destroyed earlier by bulldozing. Seventy-one wing deflectors, 10 rock dams, and 6 spring holes were created by a single bulldozer in 3 working days. Evaluation of the work 2 years later showed that 63 deflectors had successfully narrowed stream flow or created pools, rock dams were largely unsuccessful, and pools created by excavation of spring areas commonly harbored trout during warm summer weather.

INTRODUCTION

Some of Maine's finest streams for brook trout *(Salvelinus fontinalis)* have been destroyed by bulldozing preparatory to pulpwood-driving operations. The use of bulldozers in pulpwood operations has become almost universal in northern Maine in the past 10 years. This has brought about a considerable saving in time and labor, but the bulldozing, when uncontrolled, has often resulted in destructive alteration of trout-stream habitat.

River driving of logs and pulpwood has been practiced in Maine for many years and although truck transportation of logs has increased with the improvement of roads and trucking facilities, river transportation is still necessary in some inaccessible areas. In these areas pulpwood is driven down small streams and large rivers to railroad loading areas, from whence it is hauled to the mill. Prior to driving in small streams, pulpwood is cut in 4-foot lengths and piled on bank landings and in the stream bed. Stream obstructions that might hinder driving the pulpwood downstream are removed by bulldozing and often the entire length of a stream worked. Pulpwood driving is aided by release of water impounded by logging dams.

Detrimental effects of bulldozing on Maine streams were first noted by Bond and DeRoche (1950) in a state-wide survey of stream obstructions. The following effects of stream bulldozing on trout-stream habitat in the Aroostook River drainage were noted by Warner (1956). (1) Temperature. — Destruction of shade trees and bank cover often results in summer water temperatures too warm for brook trout. Small springs are often diverted and rendered ineffective for cooling the brook. (2) Pools and cover. — Almost all overhanging banks, large boulders, logs, and debris that serve as protective cover are removed. The stream bed is leveled and nearly all pools are eliminated when depressions are filled and loops and turns are straightened (Figure 1). The natural stream width is often increased considerably, and the result is a thin sheet of water flowing over a wide, flat stream bed. Water depth is often insufficient for trout. (3) Trout food. — Aquatic insect populations, the chief food of trout, are temporarily destroyed, but the insect populations recover rapidly. Over-

FIGURE 1.—A typical bulldozed trout stream in northern Maine.

hanging vegetation is eliminated, and fewer terrestrial insects are available as trout food. (4) Siltation. — Bulldozing of haul roads and landings along brooks often results in increased siltation of gravel spawning areas and such siltation is detrimental to survival of trout eggs.

The Maine Legislature has now passed a law restricting bulldozing of streams. Drastic stream damage has been curbed to a considerable extent, but past destruction of valuable fishing water has not been rectified. The present work was undertaken to evaluate the possibility of building stream-improvement structures using the original tool of destruction, the bulldozer. In 3 working days on Big Hudson Brook, 6 springs were improved, and 71 single-wing deflectors and 10 rock dams were built. Many minor improvements were also made.

BULLDOZING OF BIG HUDSON BROOK

Local anglers once considered Big Hudson Brook one of the best trout brooks in this sparsely inhabited part of northern Maine. The brook arises in Upper Hudson Pond and flows about 7 miles into Mooseleuk Lake. Mule Brook, the main tributary, enters Big Hudson Brook about 3 miles above Mooseleuk Lake. Prior to bulldozing, the section above Mule Brook ranged from 6 to 12 feet in width with excellent shade, numerous deep pools, and cold water. The lower section was somewhat wider.

Big Hudson Brook was extensively bulldozed in 1950 from the outlet of Lower Hudson Pond to Mooseleuk Lake to clear the stream channel prior to pulpwood driving. The entire length of the stream was bulldozed except for about 1 mile of deadwater. Pulpwood was piled in the stream bed and on bank landings prior to driving.

The brook was widened up to five times its natural width by bulldozing, and following this operation there was no well-defined channel at low water levels and the small amount of water present seeped through bottom rubble. Water temperatures reached the mid-seventies, and pools and protective cover were almost completely eliminated (Figure 2). Brook trout almost disappeared.

IMPROVEMENT OF BIG HUDSON BROOK

Because trout streams need an abundant supply of spring water, good bank shade, adequate cover, and gravel riffles alternating with deep pools, and because deforestation, agriculture, and logging practices have often resulted in deterioration of original stream conditions, structures to improve trout-stream habitat have gained wide usage since advocated by Hubbs, Greeley, and Tarzwell (1932). Much of the pioneer stream improvement was done in Michigan (Leonard, 1940; Clark, 1948; Shetter, Clark, and Hazzard, 1949). The work was largely experimental using a variety of structures. Two devices, single-wing deflectors and bank cover structures, were found to serve the most needs in Michigan streams (Leonard, 1940). Gee (1952) also found that a relatively few simply designed structures met most stream-improvement needs. Shetter, Clark, and Hazzard (1949) concluded that improvement of brook trout fishing in Hunt Creek, Michigan, was the result of an increase in number, size, and depth of pools created by installation of current deflectors. Rock dams have also been used to advantage in some areas (Gee, 1952; Rounsefell and Everhart, 1953). Gee recommends restricting stream-improvement structures to small streams where maximum flood flow does not exceed 100 cubic feet per second. In most cases a considerable amount of labor and simple engineering is required for such structures.

FIGURE 2.—Big Hudson Brook after bulldozing.

In June 1956 the Great Northern Paper Company, the Aroostook River Fish and Game Club, and the Maine Department of Inland Fisheries and Game jointly undertook improvement of trout-stream habitat in Big Hudson Brook that had been destroyed by bulldozing, and for this job a bulldozer was used. Restoration of the original stream character-

istics was impossible, and the attempt was one of improving existing unfavorable conditions. The bulldozer, an Allis-Chalmers HD16 equipped with a 12-foot blade, and operator were furnished by the Great Northern Paper Company. Unfortunately, high water conditions prevented the most efficient utilization of the bulldozer for building improvement structures. The type of improvement structure that could be made with a bulldozer was limited. Conventional careful placement of construction materials was not possible, because it was necessary to use the bulldozer blade for construction. The following types of improvements were made by use of the bulldozer.

Single-wing deflectors

Single-wing deflectors were constructed from available bottom material. The primary purpose of these deflectors was to constrict the stream channel and scour a pool below the deflector by utilizing the increased cutting power of the stream flow. Shallow pools were also dug above the deflector with the bulldozer blade while obtaining construction materials from the stream bed. Diversion deflectors were located to block meandering side channels to concentrate stream flow in low water periods. Most deflectors were 20 to 60 feet long, 3 to 5 feet high, and angled downstream 30 to 45 degrees (Figure 3). Several diversion deflectors over 100 feet long were built to block side channels. Most of the deflectors were at least 4 feet thick at the base.

Rock dams

Ten dams were built of large rubble and boulders. The purpose of the rock dams was to impound a pool above and to create a pool below the dam by scouring. Dams were built below small springs at several places in an attempt to impound cold water. Most rock dams were 15 to 30 feet long and 3 to 4 feet high (Figure 4).

FIGURE 3.—A single-wing boulder deflector built by a bulldozer.

FIGURE 4.—A rock dam built by a bulldozer.

Spring holes

Work was done on six small springs to increase their effectiveness in cooling brook water and to serve as hot weather "carry-over" areas for trout. Pools were excavated where the springs entered the brook, and some spring outlets were diverted into pools created by wing deflectors and rock dams (Figure 5).

EVALUATION OF IMPROVEMENT STRUCTURES

The improvement structures so made were inspected 2 years after construction to evaluate their permanence and influence on stream habitat. This evaluation is summarized in Table 1.

Single-wing deflectors

After 2 years 37 deflectors were virtually unaffected by freshets. Twenty-six deflectors were partly washed out, but they were still effective for creating pools and channeling stream flow. Eight wing deflectors were either washed out or were ineffective. Twenty-six deflectors in the upper section were considered successful, and six deflectors were partly successful. Only one deflector in the upper section of the brook was considered unsuccessful (Table 1). Deflectors in the lower section of the brook were more affected by freshets,

principally because of increased volume flow introduced by Mule Brook. Many of the deflectors in the lower section were made of small rubble and gravel. Structures made of large boulders and rubble in the lower section of the brook were also frequently partially washed out. Gravel and rubble structures in the upper section were more often washed out than structures of larger material, but many structures of fine material held very well.

Even though most structures of fine material in the lower reaches were partly washed out, many structures had achieved the desired purpose by creating pools, building up gravel bars, and successfully constricting flow.

Rock dams

Rock dams were largely unsuccessful. Even those built of large boulders washed out, creating obstacles to fish migration in some cases. The wings of several partly destroyed structures, however, served as current deflectors, and a few small pools were created. A major cause of failure of the rock dams was probably the method of construction. Gee (1952) stressed the importance of rock shape and placement in rock dam construction, and the dams built with the bulldozer blade were of rocks piled up without attempting to "key" into existing bottom materials.

Spring holes

In three spring holes where improvement was considered successful pools 6 to 30 inches deep in low water had been created. Young-of-the-year trout were moderately abundant in these areas whereas few had been seen here previously. Shallow pools were created in three other springs, and young-of-the-year trout were common after improvement. The effectiveness of the spring-hole improvement was increased in most cases by the presence of pools created by adjoining wing deflectors.

FIGURE 5.—Excavated spring hole and diversion deflector.

TABLE 1.—*Number of structures constructed by bulldozer in Big Hudson Brook and extent of success after 2 years*

Structure	Number successful	Number partly successful	Number unsuccessful
Wing deflector			
Above Mule Brook	26	6	1
Below Mule Brook	11	20	7
Rock dam	0	4	6
Spring holes	3	3	0
Total	40	33	14

DISCUSSION

Results from using a bulldozer for stream improvement in Big Hudson Brook were encouraging despite some limitations. Seventy-one wing deflectors, 10 rock dams, and 6 spring holes were created on Big Hudson Brook by a single bulldozer in 3 working days. Numerous pools were formed, stream flow was concentrated, and side channels were blocked. The limited summer stream flow was effectively channeled in some areas by deepening one side of the widened stream bed with the edge of the bulldozer blade. While the original stream conditions have in no way been restored, a brook made useless as trout habitat by bulldozing has been improved to a point where some trout can exist during the summer. It appears that in Maine, where many miles of once-productive trout streams have been destroyed by bulldozing, chosen areas of these small streams can be benefited by construction of planned stream-improvement structures using a bulldozer.

LITERATURE CITED

BOND, LYNDON H. AND STUART E. DEROCHE. 1950. A preliminary survey of man-made obstructions and logging practices in relation to certain salmonid fishes of northern Maine. Maine Dept. Inland Fish. and Game, Augusta, Maine, 47 pp.

CLARK, O. H. 1948. Stream improvements in Michigan. Trans. Am. Fish. Soc., 75: 270-280.

GEE, MERLE A. 1952. Fish stream improvement handbook, 1952. Pub. Forest Service, U.S. Dept. Agric., 21 pp.

Hubbs, Carl L., John R. Greeley, and Clarence M. Tarzwell. 1932. Methods for improvement of Michigan trout streams. Mich. Dept. Conserv., Bull. Inst. Fish. Res. 1, 54 pp.

Leonard, J. W. 1940. Some comments on stream improvement in Michigan. Mich. Conservation, 10 (2): 6, 7, 10.

Rounsefell, George A. and W. Harry Everhart. 1953. Fishery science: its methods and applications. John Wiley & Sons, Inc., New York. xii + 444 pp.

Shetter, David S., O. H. Clark, and Albert S. Hazzard. 1949. The effects of deflectors in a section of a Michigan trout stream. Trans. Am. Fish. Soc., 76: 248-278.

Warner, Kendall. 1956. Aroostook River salmon restoration and fisheries management. Maine Dept. Inland Fish. and Game and Atlantic Salmon Comm., Fish. Res. Bull. 4, 66 pp.

Uniformity of Dispersion of Sulfamerazine in Pelleted Trout Food

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ABSTRACT

Medicated food pellets for trout were prepared using 1.5 percent by weight sulfamerazine. Mixing and pelleting methods are described. Samples of pellets, taken at random during pelleting, were analyzed colorimetrically for sulfamerazine 2 days after pelleting and after storage of the pellets at 41° F. for 2 months. The sulfamerazine was found to be quite evenly mixed in the pellets and no loss detected after storage for 2 months.

INTRODUCTION

The efficacy of antimicrobial drugs for control of fish diseases depends largely upon maintenance of the prescribed amount during the period of treatment. If the dosage exceeds the optimum treatment level, there is danger that the fish being treated may be injured by toxic side effects of the drug. If the dosage is too low, all disease organisms will not be suppressed and development of drug-resistant mutant bacteria encouraged. It is generally recognized that chemotherapeutic drugs are primarily bacteriostatic in action and by interfering with the multiplication of bacteria provide an opportunity for the normal defense mechanisms of the fish to destroy the invader.

Since mixing of drugs with food fed to trout is the only practical way to administer internal medication, it is essential that the drug be evenly mixed with their diet. It is necessary to know the optimum dosage rate and the exact dosage per pound of food being fed. Since the development of a special pelleted trout diet in Minnesota as described by Schumacher (1958) the therapeutic drugs have usually been added to the standard dry-meal formulas and then this mixture pelleted by a local milling company.

Preparation of medicated pellets raised three questions: (1) is the drug evenly mixed with the food components of the pellet; (2) is there a chemically detectable loss of drug as a result of the pelleting process; and (3) is there any change in the concentration of the drug in the pellets during the several weeks it must be stored for a prolonged treatment of the fish. The present paper considers these questions as related to pellets made up to contain 1.5 percent by weight sulfamerazine.

MIXING OF FOOD

For therapeutic use 2,000 pounds of pellets containing 1.5 percent sulfamerazine were needed. The preparation of these pellets was as follows:

A. Thirty pounds of sulfamerazine U.S.P. were added to 70 pounds dried brewer's yeast and mixed for 10 minutes at 30 R.P.M. in a MacLellan No. 1 vertical-axis trace premixer. This is an end-over-end tumbling mixer.

B. To the 100 pounds of the foregoing mix 100 pounds more of dry brewer's yeast were added and the whole mixed again, as in "A," for 10 minutes.

C. To the 200 pounds of mix so prepared, 1,800 pounds of standard Minnesota dry trout food meal were then added and the whole mixed for 10 minutes at 40 R.P.M. in a Strong-Scott horizontal triple-action mixer, producing the 2,000 pounds of medicated food needed. The meal was then pelleted in 1/8-inch pellets in a California-type pellet mill containing dies designed to avoid excessive pressure.

SAMPLING AND ANALYSES

As the pelleting was being done, pellets were collected at random to make up four 25-gram samples (each about 1,000 pellets). To eliminate possible contamination from any material remaining in the pelleting machine from earlier jobs, no pellets were collected during the first half-hour of its

operation. Each of the four pellet samples was separated into five sub-samples to obtain a total of 20 samples for analysis. Each of the 20 samples was placed in a screw-capped vial and the lot stored at 5° C. (41° F.) until analyzed.

The method used for quantitative analyses of sulfamerazine in the pellets was a modification of that of Fuller (1937) for sulfonamides in blood, as adapted for the colorimeter by Jang and Cheng (1943). The basis of this method is that sulfonamides in dilute trichloracetic acid produce a yellow color when an alkaline solution of thymol is added. To use the spectrophotometer (ours is a Coleman Junior, Model 6A instrument) for determining density of the yellow color formed, it was first necessary to determine whether or not light absorbtion by the yellow color formed follows Beer's Law (a logarithmic relationship).

Standard concentrations of sulfamerazine were first prepared. A stock solution was made by dissolving 100 milligrams of dry sulfamerazine U.S.P. powder in a liter of distilled water. This stock solution of 100 p.p.m. sulfamerazine was stored in the dark at 5° C. (41° F.). For comparison with solutions of sulfamerazine extracted from the pellets and for checking the applicability of Beer's Law to this analysis, ten 100-milliliter dilutions of the stock solution were made. using 5 percent by weight aqueous solution of trichloracetic acid as the diluting agent. Concentrations of sulfamerazine in these dilutions ranged from 0.05 to 0.50 milligrams per 100 milliliters (0.5 to 5.0 p.p.m.) with a difference of 0.5 milligrams between dilutions (0.05 p.p.m.). It was expected that, with extraction method used, the concentration of sulfamerazine in the pellet extract would be about 2.5 p.p.m.—the approximate center of the range of standards—assuming even dispersal of the drug in the pellets.

Upon checking the color density formed by the standards with reagents with the spectrophotometer it was found that, within this range of concentrations, the relationship between optical density (light transmission) and concentration followed Beer's Law. The values showed a straight line relationship on a semi-logarithmic graph paper and allowed interpolation of immediate values in the usual way.

Sulfamerazine in the pellets was extracted by placing 2.5 grams of finely ground pellet material (ground with mortar and pestle) in a 500-milliliter volumetric flask containing 250 milliliters of distilled water. The flask was shaken for 5 minutes, distilled water added to the 500-milliliter mark, and mixed by inversion for 5 minutes. The material in the water was then allowed to settle for 5 minutes. From the clear supernatant solution in the flask 2 milliliters were pipetted into a 50-milliliter volumetric flask containing 25 milliliters of 5 percent by weight aqueous solution of trichloracetic acid. The trichloracetic acid acts as a deproteinizing agent. The flask was then shaken for 5 minutes, distilled water added to the 50-milliliter mark, and mixed again for 1 minute by flask inversion. The solution was then filtered through No. 42 Whatman's filter paper and 20 milliliters of the filtrate added to a 19- by 105-millimeter spectrophotometer cuvette tube together with 2.0 milliliters of 0.5 percent by weight aqueous solution of sodium nitrite. This solution was mixed with a glass rod and allowed to stand in the cuvette for 3 minutes. Then exactly 4.0 milliliters of a 0.5 percent (by weight) solution of thymol in 5N sodium hydroxide was added. It was found that the orange-yellow color of the diazotized sulfonamide developed at once and remained stable more than 6 hours when refrigerated.

Spectrophotometer readings of optical density were made with light at a wave length of 450 millimicrons. A blank (color control) made fresh daily from sulfonamide-free pellets was used for setting the instrument at 100 percent transmission when reading the unknowns. Distilled water was used as a blank for prepared standards.

RESULTS AND DISCUSSION

Results of the analyses of the five subsamples in each sample of pellets analyzed shortly after preparation are shown in Table 1. It will be noted that individual subsample analyses ranged from 1.008 to 2.113 grams of sulfamerazine per 100 grams of medicated food with means for these four samples ranging from 1.183 to 1.346 grams. All but two of the analyses of the individual subsamples were somewhat lower than 1.5 percent. This small apparent loss is attributed to analytical deficiencies rather than inadequate mixing. Differences between analyses proved to be not sig-

nificant at the 95 percent probability level (variance ratio F, 3.16 to 3.24) when analysis of variance was applied to the data.

Similar analyses of samples of pellets stored for 2 months at 5° C. (41° F.) gave results very similar to the freshly prepared pellets (Table 2). Sulfamerazine, as determined by analysis, ranged from 1.171 to 1.556 percent in the stored pellets. Again analysis of variance showed differences in analytical results to be not significant at the 95 percent probability level (variance ratio F, 3.24).

TABLE 1.—*Grams of sulfamerazine per 100 grams of pellet sample as determined shortly after pelleting*

Sample	I	II	III	IV
	1.723	1.203	1.008	0.683
	1.365	1.332	1.398	1.332
	1.268	1.268	1.203	2.113
	1.008	1.105	1.365	1.463
	1.365	1.008	1.268	1.105
Sample mean	1.346	1.183	1.248	1.339
Theoretical mean	1.500	1.500	1.500	1.500
Difference	0.154	0.317	0.252	0.161

TABLE 2.—*Grams of sulfamerazine per 100 grams of pellet sample as determined after 2 months storage at 5°C.*

Sample	I	II	III	IV
	1.500	1.268	1.268	1.500
	1.073	1.398	1.568	1.073
	1.040	1.203	1.568	1.332
	1.170	1.398	1.170	1.625
	1.073	1.625	2.275	1.500
Sample mean	1.171	1.378	1.556	1.406
Theoretical mean	1.500	1.500	1.500	1.500
Difference	0.329	0.122	0.056	0.094

ACKNOWLEDGMENTS

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LITERATURE CITED

FULLER, A. T. 1937. Is p-aminobenzene-sulfonamide active agent in prontosil therapy? Lancet, 1: 194-198.

JANG, C. S. AND W. S. CHENG. 1943. Method for estimation of sulfanilamide and its derivatives in biological fluids. Chinese Med. Jour., 61: 227-232.

SCHUMACHER, R. E. 1958. Experimental feeding of a pelleted trout food to large fingerling and yearling brook, brown, and rainbow trout. Prog. Fish-Cult., 20: 51-57.

Some Factors Influencing Seasonal Changes in Angler Catch in a Minnesota Lake[1]

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ABSTRACT

An investigation was undertaken in a small Minnesota lake to determine the relationship between angler success for northern pike *(Esox lucius)*, bluegill *(Lepomis macrochirus)*, and crappie *(Pomoxis nigromaculatus)* and food availability and food selectivity by these species. Fishing success was determined by creel census and food selectivity by stomach analysis of angler-caught fish. Food availability was determined by bottom sampling and shore seining for small fish. Over a 3-year period anglers' catch was highest in June and lowest in late summer. Angling success was inversely related to food availability and food intake, but changes in physical and chemical factors did not appear to be related to rate of angler take.

INTRODUCTION

Fresh-water sport fisheries management is usually based on the assumption that availability of fish to anglers is constant throughout the angling season. Angler success, however, varies greatly during the course of a season in many warm-water lakes although netting surveys do not show corresponding changes in fish abundance. The fisherman's catch is usually highest in the early part of the summer and then becomes gradually less as the season progresses. It has been suggested that the mid-season slump is associated with an increase in available food which makes game fish less likely to be caught. The present study was undertaken in the spring of 1954 to test this hypothesis. Information required for this purpose was the relationship of foods selected by fish to angling success in terms of catch per unit of effort, and the relationship of foods selected by fish to food availability in the habitat. Linwood Lake, where a continuous creel census from 1952 through 1954 showed that the catch per unit of effort was highest early in the season and declined rapidly as the season progressed, was selected for study.

In addition to measurement of trends in catch rate, seasonal changes in quality and quantity of available food and food used by game fish were determined. Estimates of available food were made from bottom samples and seine hauls, and of food selection from stomach contents of the fish. Northern pike *(Esox lucius)*, bluegills *(Lepomis macrochirus)*, and black crappies *(Pomoxis nigromaculatus)*, the species most commonly taken by anglers, were checked.

A secondary objective of the study was to determine the relationship between angler success and the physical and chemical factors that show seasonal change. Water temperature, turbidity, pH, dissolved oxygen, and total carbonates were therefore compared throughout the summer season to catch rate.

Linwood Lake

Linwood is an ice-block lake of the Anoka sand plain which lies in the Mississippi drainage basin of southeastern Minnesota. It has an area of 765 acres and a maximum depth of 35 feet (Figure 1). Most of the lake is shallow with sandy bottoms and the littoral zone contains extensive growths of aquatic plants. The recreational development consists of two boat liveries and about 35 summer cottages along the northern shore. A thermocline is present from June to mid-September and in 1954 the surface temperature varied from 60° F. at the end of May to 77° F. in July and August. Oxygen was absent in the hypolimnion during most of the summer. Water analysis has shown that the lake is moderately fertile. A total of 23 species of fish has been recorded from 1954 seine hauls and Minnesota Department of Conservation records. Fish were netted with experimental gear in the summers of 1952-54 to obtain estimates of

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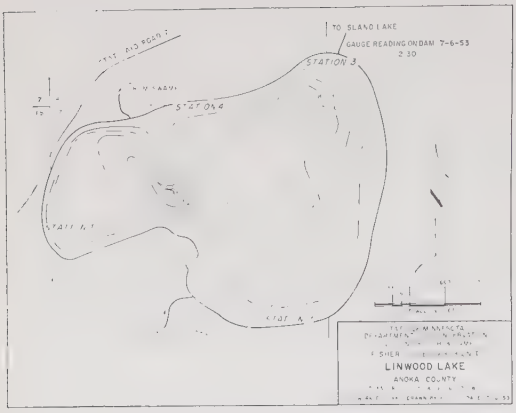

FIGURE 1.—Linwood Lake, Anoka County, Minnesota.

abundance (Table 1). In the 3 years of observation the average catch per 24-hour trap-net set dropped from 9.0 pounds in 1952 and 9.9 pounds in 1953 to 4.7 pounds in 1954. The fact that estimates of angler catch indicated a slightly higher total harvest in 1954 than in each of the 2 earlier years suggested that inadequate net sampling may have been responsible for the apparent decline in abundance.

Northern pike and crappies, the principal predator species in Linwood, are present in average and above average numbers, respectively, while the abundance of walleyes *(Stizostedion v. vitreum)* and largemouth bass *(Micropterus salmoides)* is low compared to other Minnesota lakes. The catch of sunfish per trap-net set is near the average for the state. Carp *(Cyprinus carpio)* were relatively abundant in 1946 when a rough-fish removal crew seined several thousand pounds from the lake, but were not common in 1954. Bullheads *(Ameiurus spp.)*, suckers *(Catostomus commersoni)*, and dogfish *(Amia calva)* were present in low numbers.

TABLE 1.—*Weight of fish caught in experimental nets in Linwood Lake (1952-1954), expressed as pounds per net per 24-hour set*[1]

Item	1952	1953	1954	1954
Number of nets	32	40	8	12
Type of net	Trap	Trap	Trap	Gill
Northern pike	0.92	2.14	0.61	4.33
Walleye	0.80	0.60	0.70	0.87
Perch	0.01	0.01	—	0.26
Bluegill	1.43	1.95[2]	0.41	0.04
Pumpkinseed	0.26		0.06	0.03
Largemouth bass	0.06	0.07	0.32	0.16
Crappie	3.62	4.32	1.61	0.97
Others[3]	1.93	0.85	0.98	3.41
Total fish	9.03	9.93	4.69	10.07

[1]From data compiled by the Minnesota Department of Conservation.
[2]Sunfish were not separated by species in 1953.
[3]Includes bullheads, dogfish, suckers, and carp.

Average weight of individuals of most species remained substantially unchanged over the 3-year period. Since the average weight of walleye pike was about 5 pounds and no small walleyes were caught in nets or by anglers, it is believed that the few large walleyes caught in recent years were the remains of planted stock.

Age structures of the populations of northern pike, bluegills, black crappies, and largemouth bass were estimated from scales of angler-caught fish in 1954. With the exception of crappies most of the catch of these species was furnished by fish of the middle age groups. Northern pike and bass are first caught in significant numbers during their fourth year; bluegills reached good catchable size in the fifth growing season; and fish in their third year supplied a substantial proportion of the total crappie catch in late summer. Since third-year crappies outnumbered other age groups in the catch during 1954, the 1952 year class probably was unusually strong and contributed more to the catch than an average year class. The 1951 year class contributed little and was probably weak. Growth rates of the various species, estimated from average lengths of age groups, were found to be slightly greater than statewide mean growth rates.

Current regulations in Linwood permit year-around angling for sunfish and crappies, winter angling for walleyes and northern pike, winter spearing of northern pike, and summer angling for pike and other species. Between 1910 and 1945 hatchery-reared fry and fingerlings of walleye and northern pike, crappies, sunfish, and largemouth bass were planted. Rough fish, especially carp and dogfish, have been removed with seines or traps at various times.

Catch by anglers

Data from the creel census operated by the Minnesota Department of Conservation from 1952 through 1954 on Linwood Lake to determine fish population structure, angler catch, and the value of management practices, were used in the present study. The census sup-

plied estimates of the number of fishermen, number of fishing trips, hours of fishing effort, total catch, and catch composition by species and sizes (Moyle and Franklin, 1953) and was based on a stratified sampling pattern which included only certain days in a census period. Summaries were based on a 10-week period. On each census day counts of shore and boat fishermen were made at 2-hour intervals and clerks attempted to contact at least half of the fishing parties at trip completion. Estimates of total catch based on these sampling methods had some limitations. Weather probably introduces the greatest error. If several census days in a period had inclement weather, the fishing load was reduced and the calculated fishing intensity was lower than the real value. In the present study unexpanded census information only was used in comparisons with food availability and food selectivity.

As previously mentioned the principal angler-caught fish in Linwood are northern pike, bluegills, and crappies. Yellow perch *(Perca flavescens)*, pumpkinseed *(Lepomis gibbosus)*, bullheads *(Ameiurus spp.)*, largemouth bass, and walleye pike were also taken. In 1952-1954 the latter group made up about 5 percent of the total numbers caught.

The summer creel census began May 15 in 1952 and 1953 and in the last week in April in 1954. Thirty-eight days were checked in the summer of 1952, 64 days in 1953, and 58 days in 1954. Angler catch of northern pike, crappie, and sunfish, and of the three species combined was summarized by semi-monthly intervals (Table 2, Figure 2). The catch rate for sunfish was highest in June and for crappies it was highest in July. More northern

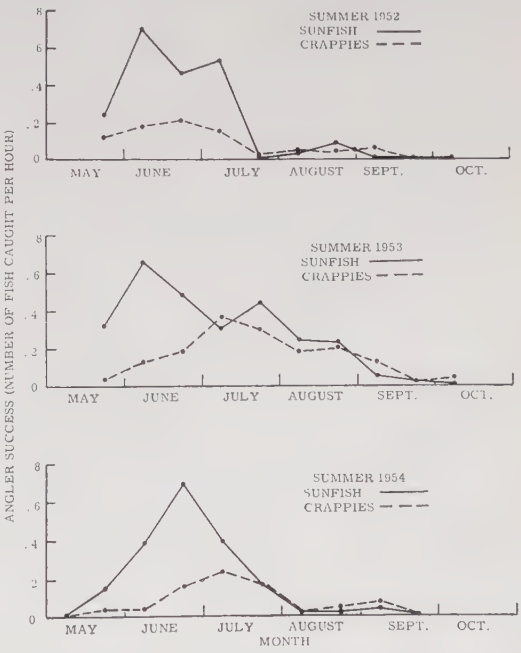

FIGURE 2. — The average number of sunfish and crappies caught per angler-hour at Linwood Lake in 1952, 1953, and 1954, as shown by census information.

TABLE 2.—*Estimated average numbers of northern pike, sunfish, and crappies taken per angler-hour at Linwood Lake during the summer seasons of 1952, 1953, and 1954*[1]

Year and Species	Average numbers of fish caught per angler-hour									
	May	June		July		August		September		October
	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15
1952										
Northern pike	0.08	0.05	0.03	0.02	0.04	0.03	0.05	0.06	0.04	0.00
Sunfish	0.24	0.70	0.46	0.53	0.00	0.03	0.09	0.01	0.00	0.00
Crappie	0.12	0.19	0.21	0.15	0.21	0.04	0.04	0.06	0.01	0.00
Total	0.44	0.94	0.70	0.70	0.25	0.10	0.18	0.13	0.05	0.00
1953										
Northern pike	0.17	0.05	0.03	0.01	0.02	0.04	0.02	0.05	0.07	0.07
Sunfish	0.32	0.66	0.48	0.30	0.44	0.24	0.23	0.05	0.02	0.00
Crappie	0.03	0.13	0.19	0.37	0.30	0.18	0.20	0.13	0.02	0.04
Total	0.52	0.84	0.70	0.68	0.76	0.46	0.45	0.23	0.11	0.11
1954										
Northern pike	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.04	0.23
Sunfish	0.15	0.38	0.69	0.39	0.16	0.02	0.02	0.04	0.00	0.00
Crappie	0.04	0.04	0.16	0.23	0.17	0.03	0.04	0.07	0.01	0.00
Total	0.23	0.44	0.86	0.63	0.34	0.06	0.07	0.11	0.05	0.23

[1]Data are from census records of the Minnesota Department of Conservation.

pike were caught at the beginning and near the end of each season than in midsummer, but the low rate of catch does not permit a reliable assessment of seasonal changes. Average catch per hour of pike and panfish combined was highest in June and July of each season. Estimates of total numbers and pounds of all fish taken by the summer anglers, 1952-1954, (Moyle and Franklin, 1953, 1954, and 1955) indicate that the grand totals, and in many cases the totals for individual species, are very similar from year to year (Table 3). Summer angling effort in 1954 was considerably greater than in the 2 previous years of the census, but this increase was not accompanied by larger catches (Tables 2 and 4).

Table 4.—*Estimated fishing effort by summer anglers at Linwood Lake, 1952-1954, expressed as total man-trips, total man-hours, hours per acre, and average length of each trip*[1]

Year	Man-trips	Man-hours	Hours per acre	Hours per trip
1952.....	11,449	43,970	57.4	4.4
1953.....	11,023	39,239	51.3	3.7
1954.....	15,918	54,172	70.8	3.7

[1]Data are from creel census records of the Minnesota Department of Conservation.

ANGLER CATCH IN RELATION TO AVAILABLE AND SELECTED FISH FOOD

Available fish food has been measured in various ways in previous studies. Surber (1929) stated that fish selected food on the basis of relative abundance and conspicuousness. Hess and Swartz (1941) defined available food as "organisms which are capable of being eaten by a fish if he so desires". In the Linwood study all animal food of edible size was considered to be available food.

Food availability and angler catch

Considerable variation in the shallow-water habitat of Linwood was noted, especially with respect to vegetation types. Since it was desirable to obtain estimates of available food that were representative of the entire lake, four stations characteristic of the principal vegetation and bottom types were used for sampling of the bottom fauna and forage fish (Figure 1).

Bottom organisms.—Bottom samples were taken with a Petersen dredge in water 2 to 5 feet deep at approximately semi-monthly intervals from May 1 to October 15, 1954. Samples were washed through a 40-mesh sieve, insect larvae were identified to order or family, and other organisms to class or order. Organisms in each group were counted and the volume of all animals in each sample, exclusive of mollusks, was measured by alcohol displacement. Samples taken on the same day at the four stations were combined and summarized by months to provide an appraisal of seasonal trends in numbers (Table 5). Total number of bottom organisms was at an intermediate level in May 1954, and decreased slightly in June following emergence of insects. After the June low the numbers gradually increased to a peak in September. This general pattern of invertebrate abundance was similar to one reported from a Michigan lake (Ball, 1948).

Table 3.—*The summer angler catch taken from Linwood Lake, 1952-1954, expressed as total numbers and pounds of fish*[1]

Item and year	Species								
	Northern pike	Sunfish	Crappie	Perch	Bullhead	Bass	Walleye	Other[2]	Total
1952									
Number.....	2,102	16,385	6,848	1,209	417	302	10	—	27,273
Weight.....	4,859	5,410	2,348	242	357	770	60	—	14,046
1953									
Number.....	2,043	15,033	8,455	527	335	208	43	—	26,644
Weight.....	4,013	4,474	2,514	54	269	455	187	—	11,966
1954									
Number.....	1,127	19,291	6,309	509	380	221	6	7	27,850
Weight.....	2,756	8,148	2,066	62	567	511	38	21	14,169
Mean number..	1,757	16,903	7,204	748	377	244	20	2	27,253
Mean weight...	3,876	6,011	2,309	119	398	579	95	7	13,394

[1]Minnesota Department of Conservation estimates based on creel census.
[2]Includes bullheads, carp, and suckers.

TABLE 5.—*Available food in Linwood Lake estimated from bottom samples and expressed as percentage of total number of organisms present during each month—1954*

Item	May	June	July	August	September	October
Ephemeroptera	0.2	1.3	34.2	4.7	0.7	1.0
Odonata[1]	—	0.4	0.1	0.4	0.3	0.3
Trichoptera[2]	1.0	1.1	0.8	6.6	3.1	8.8
Coleoptera[3]	—	—	0.8	0.1	0.1	—
Chironomidae	90.8	85.2	19.3	14.4	10.2	16.6
Tabanidae	—	0.8	0.5	1.1	0.2	0.1
Hyalella	2.1	3.1	32.6	57.7	74.0	55.9
Hydracharina	—	—	0.1	T[5]	T	—
Hirudinea	1.6	1.9	8.3	5.2	2.8	1.6
Oligochaeta	3.2	5.8	2.9	2.3	1.2	4.5
Sphaeriidae[4]	—	—	—	1.7	1.9	2.0
Gastropoda[4]	—	—	—	4.4	3.1	8.2
Turbellaria	0.7	0.2	0.1	1.3	2.3	1.0
Nematoda	0.4	0.2	0.3	0.1	0.1	—
Total	100.0	100.0	100.0	100.0	100.0	100.0
Volume in cubic centimeters per square foot[6]	1.3	0.4	0.9	1.0	1.4	1.4

[1]Principally Coenagrionidae.
[2]Principally Leptoceridae (caddis flies were removed from cases).
[3]Principally Chrysomelidae.
[4]Not tallied with August.
[5]Trace.
[6]Exclusive of Mollusca.

Forage fishes.—A 30-foot, ¼-inch mesh seine, with a lining of 5/32-inch netting in the center section, was used to make semimonthly hauls at the four stations during the summer season. Each haul covered approximately 3,000 square feet. All young-of-the-year (O-group) fish taken were preserved in formalin while older fish were counted and a representative sample saved. Some catchable-size fish were retained for stomach analysis. Fish were separated into O-group and older fish by species, and the number and average total length in millimeters of each group were determined. Forage-size fish from seine hauls at all stations were combined and summarized to obtain the average number of each species per 10,000 square feet of surface area (Tables 6 and 7). "Forage-size" was arbitrarily

TABLE 6.—*Average numbers of fish seined per 10,000 square feet of surface area in Linwood Lake, May through July, 1954*[1]

Species	Age	Month and day						
		May 8	June 12	June 18	June 29	July 9	July 15	July 27
Spottail shiner	yy[2]	—	—	205	48	121	159	1
Spottail shiner	ad[3]	850	3	—	—	—	—	—
Golden shiner	yy	—	—	—	—	—	2	2
Bluntnose minnow	yy	—	—	—	2	23	16	242
Bluntnose minnow	ad	6	—	17	5	1	7	5
Fathead minnow	ad	—	1	2	2	—	—	—
Carp	yy	—	—	—	—	—	3	1
Johnny darter	yy	—	—	2	8	35	32	128
Johnny darter	ad	—	18	5	—	1	10	4
Iowa darter	yy	—	—	—	2	3	—	9
Iowa darter	ad	—	—	1	1	—	—	—
Killifish	yy	—	—	—	—	2	11	31
Killifish	ad	—	24	6	4	6	7	5
Yellow perch	yy	—	2	1	1,350	564	369	239
Yellow perch	I	343	8	54	161	240	244	206
Sunfish	yy[4]	—	—	—	12	1,771	805	525
Bluegill	I	—	2	1	—	—	2	3
Pumpkinseed	I	—	—	—	8	1	1	—
Largemouth bass	yy	—	—	1	25	30	122	64
Largemouth bass	I	2	—	—	1	1	—	—
Northern pike	yy	—	—	—	1	1	3	—
Black crappie	yy	—	—	—	1	5	2	2
Black crappie	I	5	—	—	—	—	—	—
Brown bullhead	yy	—	—	—	—	—	2	3
Tadpole madtom	yy	—	—	—	—	—	—	1
Total (all fish)		1,206	58	295	1,631	2,805	1,797	1,471
Total (yy fish)		—	2	209	1,449	2,555	1,527	1,248

[1]Fish from all four sampling stations are combined and the average numbers are weighted for all stations. Fish, other than minnows, of more than one annulus are not included in the table.
[2]Young-of-the-year.
[3]Adult.
[4]Pumpkinseeds and bluegills were combined in early post-larval stages because they were not readily separable.

chosen as the length at I-annulus or less in the case of larger species such as sunfish, carp, and perch, but included all sizes and ages of the minnows and other small species. This choice was based on sizes of fish found in stomachs of game species.

Young-of-the-year bluegills and pumpkinseeds during early stages were grouped together because they were not easily separated in the field, but young-of-the-year and I-annulus fish were tallied separately since they differed in seasonal abundance. The total number of O-group fish of a species rises to a maximum at some period during the season, depending upon spawning time, and then gradually drops. Older fish, however, continually decline in numbers as the season progresses.

The number of O-group fish taken on a particular date did not always agree with what might be predicted from the preceding sample. Such apparent changes in abundance may have been due in part to sampling error, but may also have been actual changes caused by the addition of fish from late hatches. To minimize error the samples were combined by monthly intervals (Table 8). Since only O-group fish were numerous enough in all months to show the trends in seasonal abundance, older fish were not included in the monthly summaries. Peaks of abundance of spottail shiners and yellow perch were somewhat earlier than the peak of sunfish, while the peak for the latter was earlier than that for bluntnose minnows. Average abundance of all young fish combined was at a maximum in July.

Assuming that seine-caught fish were caught in proportion to their abundance, sunfish and yellow perch were the most abundant species present. Although crappies rank high on the list of angler-caught fish in Linwood, few young crappies were found in seine catches, possibly because there was limited survival of spawn in 1954.

While bottom samples and seine hauls provide some measure of available food in a lake, these sampling methods have limitations. All microscopic aquatic invertebrates were not caught in the Petersen dredge, as is later shown by stomach analyses. Other animals were probably not always taken in proportion to their abundance because vegetation sometimes prevented the dredge jaws from closing

TABLE 7.—*Average numbers of fish seined per 10,000 square feet of surface area in Linwood Lake, August through October, 1954*[1]

Species	Age	Month and day						
		August 14	August 28	September 7	September 17	September 24	October 5	October 17
Spottail shiner	yy	—	3	—	4	—	5	4
Spottail shiner	ad	—	1	—	—	—	—	—
Golden shiner	yy	1	9	—	2	27	—	—
Bluntnose minnow	yy	497	86	221	22	19	7	1
Bluntnose minnow	ad	8	—	—	—	—	—	—
Fathead minnow	yy	—	—	—	—	2	1	—
Fathead minnow	ad	1	—	—	—	1	—	—
Carp	yy	1	1	—	—	1	—	—
Johnny darter	yy	155	10	52	30	22	24	4
Johnny darter	ad	1	1	—	—	1	1	—
Iowa darter	yy	23	—	14	3	2	2	1
Iowa darter	ad	—	—	1	—	—	—	—
Killifish	yy	68	24	222	42	15	14	1
Killifish	ad	14	2	44	8	1	1	—
Mud minnow	yy	—	1	1	1	—	2	—
Yellow perch	yy	354	72	270	335	69	75	32
Yellow perch	I	102	120	80	86	180	79	26
Bluegill	yy	—	—	1,107	617	991	564	445
Pumpkinseed	yy	856[2]	771[2]	50	44	90	10	6
Bluegill	I	—	3	—	—	8	—	—
Pumpkinseed	I	—	8	7	—	6	—	1
Largemouth bass	yy	38	39	28	20	14	10	7
Northern pike	yy	1	2	3	2	1	1	2
Black crappie	yy	1	—	4	—	1	—	1
Black crappie	I	5	—	—	2	2	—	—
Brown bullhead	yy	1	1	—	1	2	—	—
Yellow bullhead	yy	4	—	—	—	—	2	—
Tadpole madtom	yy	—	—	—	—	—	4	—
Total (all fish)		2,130	1,154	2,104	1,219	1,455	802	531
Total (yy fish)		2,000	1,019	1,972	1,123	1,256	721	504

[1]See explanatory notes in Table 6.
[2]See note 4, Table 6

TABLE 8.—*Average numbers of O-group fish seined per 10,000 square feet of surface area in Linwood Lake each month in the 1954 season*

Item	June	July	August	September	October
Area seined (square feet)	50,000	39,000	20,000	34,000	26,000
Spottail shiner	116	106	1	1	4
Golden shiner	—	1	5	12	—
Bluntnose minnow	1	77	310	71	4
Killifish	—	12	48	76	7
Johnny darter	4	58	89	32	14
Iowa darter	1	4	12	5	1
Yellow perch	486	426	226	205	53
Bluegill	—	—	—	901	502
Pumpkinseed	4[1]	1,180	817	65	8
Black crappie	1	3	1	1	1
Largemouth bass	10	65	38	19	8
Total	623	1,932	1,547	1,388	602

[1]Bluegills and pumpkinseeds are combined prior to September.

tightly. In addition, this gear does not effectively sample small organisms like amphipods which live just off the bottom. Thick growths of aquatic plants cut seining efficiency at times and during the latter part of the season it became difficult at two stations to complete a haul without losing part of the catch. Since these sources of error are known to be present, it is believed that the estimates are adequate only for showing general trends.

Influence of food availability on rate of catch.—If angler success varies inversely with food availability, a comparison of creel census returns and trends in food abundance should show this relationship. A comparison of trend in fishing success and food availability was made with the 1954 data (Figure 3). Fishing success is expressed as combined numbers of sunfish, crappies, and northern pike caught per hour of fishing. Available food is expressed as numbers of O-group fish caught per 1,000 square feet seined and as volumes of bottom invertebrate fauna per square foot of bottom sampled. These data show that a reciprocal relationship existed between total food supply and angler catch during the summer season. In the middle of June, when available food had fallen to its lowest level, angler success approached the seasonal peak. In mid-July, as the available food supply climbed, the catch of fish was reduced. The numbers of O-group fish declined after mid-July, but their rapid increase in weight increased the food supply during this period.

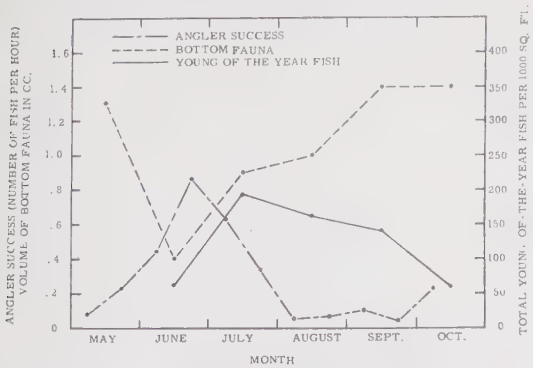

FIGURE 3.—Angler success and available food in Linwood Lake during the 1954 season. Food does not include mollusks.

Food utilization and angler catch

Stomachs of fish caught by anglers were collected to compare food utilization and angler catch rate. During the latter part of the summer fishing season, when angler success was low, some stomachs were obtained from seine-caught fish. No food other than fish was found in pike stomachs, while crappies contained both invertebrates and fish. Bluegills fed on both invertebrates and plants. Volumes of fish and invertebrate food were measured separately by alcohol displacement and food identified as bait was discarded. The type of plant food found in bluegill stomachs was noted and an estimate of its proportion of total food was made. All organisms in stomachs were identified and counted. Invertebrates were identified, where possible, to the same groups used in identification of bottom-sample fauna; fish were identified to species and note was made of ages (*i. e.*, O-group or older). Digestion in some cases prevented species identification of fish, but usually size indicated whether or not they were from the current year class.

Northern pike.—Stomachs from 45 northern pike were obtained during 1954. Early in

the season samples were collected from angler-caught fish, but later most specimens were obtained from seine hauls. Although the number of analyses was small, a definite change in the size of fish eaten was noted as the season progressed. In May only fish older than young-of-the-year were selected; in mid-season both O-group and older fish were utilized; and in the latter part of the season pike food consisted almost entirely of O-group fish (Table 9). Catch rate of pike was highest when the proportion of stomachs containing food was lowest.

Most of the fish used by pike in May were I-annulus and older perch, with the former predominating. Young-of-the-year fish of edible sizes had not yet appeared in the lake. From late June to mid-September perch continued to be the principal species taken with O-group fish being substantially used. In late September and October O-group perch and sunfish were taken in nearly equal numbers with perch supplying the greater volume because they were larger in size.

The size of fish selected appeared to be dependent upon relative availability. Small fish of the 1953 year class were selected when they were comparatively plentiful, but when O-group fish became abundant the pike used them in increasing numbers. Fish older than O-group were less available as they became too large to be eaten and as their numbers declined.

Food habits of pike in Linwood are similar to those reported by other workers (Pearse, 1918; Forbes and Richardson, 1920). Frost (1954) showed that northern pike in an English lake fed almost entirely upon fish, with perch occurring in the diet at all times but predominantly from May to October. She attributed this seasonal variation in the selection of perch to changes in the habits of prey species and concluded that abundance and availability rather than selection by pike determined which fish were eaten. Stomach analyses and seine-haul data suggest that these factors also determined food utilization by Linwood pike.

Bluegill sunfish.—Stomachs from 104 bluegills were collected from the 1954 angler catch. Different organisms found in the stomachs were counted only, but total volume of contents was measured in all cases. Immature insects (principally chironomids and trichopterans), hydracharinids, and cladocerans were the most important animal food in the diet (Table 10). Cladocerans, among which *Daphnia* spp. predominated, were of major importance only in the early part of the season, while hydracharinids were heavily utilized in both May and July. Mollusks were taken in small numbers throughout the summer.

As summer progressed bluegills ingested increasing amounts of rooted plant material, primarily narrowleafed pondweeds *(Potamogeton* spp.) (Figure 4). The average volume of food taken by bluegills rose as the season advanced, but the volume of invertebrates dropped while the plant intake rose sharply. In late July the average total volume of invertebrate food was below that of May. The diet of bluegills reported by other workers (Forbes and Richardson, 1920; Ball, 1948) agrees closely with the Linwood results.

Condition factor (C) was calculated for all bluegills included in food studies from the formula:

$$C = \frac{100{,}000W}{L^3},$$

where W is fish weight in pounds and L is total fish length in inches. The condition factor rose from 80 in late May to about 85 in

TABLE 9.—*Species and sizes of fish selected by northern pike in Linwood Lake during the 1954 season*

Date interval	Total fish	Empty stomachs	Fish in pike stomachs	
			Young-of-the-year	I–Annulus or over
May 15-30	21	10		12 perch 5 other[1]
June 26-September 17	9	2	3 perch 1 sunfish 2 other	3 perch 3 other
September 24-October 17	15	4	5 perch 5 sunfish 5 other	1 bullhead

[1]Includes unidentified fish, most of which were minnows.

TABLE 10.—*The animal food of catchable-size bluegills in Linwood Lake during the 1954 summer season, expressed as number and percentage of organisms per stomach*

Item	May		June		July	
	Number	Percentage	Number	Percentage	Number	Percentage
Total stomachs	12		36		57	
Empty stomachs	0		3		4	
Ephemeroptera	T[1]	T	0.8	1.3	0.5	0.5
Odonata	0.3	0.1	0.5	0.8	0.1	0.1
Hemiptera	—	—	0.2	0.3	T	T
Trichoptera	4.5	1.6	10.9	18.1	4.8	4.7
Coleoptera	—	—	0.4	0.7	0.2	0.2
Chironomidae	18.0	6.5	15.4	25.5	23.5	23.1
Chaoborinae	16.9	6.1	T	T	T	T
Ceratopogonidae	T	T	0.5	0.8	T	T
Cladocera	94.5	34.0	3.8	6.3	—	—
Hyalella	7.3	2.6	1.7	2.8	6.9	6.8
Hydracharina	135.2	48.6	19.8	32.8	57.4	56.5
Copepoda	—	—	0.4	0.7	T	T
Ostracoda	—	—	—	—	0.5	0.5
Hirudinea	T	T	T	T	—	—
Sphaeriidae	—	—	3.2	5.3	2.4	2.4
Gastropoda	1.5	0.5	2.8	4.6	5.3	5.2
Total	278.2	100.0	60.4	100.0	101.6	100.0

[1]Trace.

June and then fell to 80 again in early July. In the last half of July it rose slightly to about 82. Spawning activity in late June and early July probably caused the drop in average condition, but the slight rise in late July indicated that bluegills were subsisting well on a predominantly vegetable diet.

Little relationship is shown by a comparison of invertebrates taken in bottom samples (Table 5) and food selected by bluegills in 1954 (Table 10). Certain organisms, such as plankters, occurred regularly in stomachs but were either not caught at all in the bottom sampler or were inadequately sampled.

In the last half of May a total of eight food items was selected by bluegills in significant amounts; in June, 13 items; and in July, 10 items. From May 15 to July 31 the number of items taken in bottom samples increased slightly. The reduction in the number of animal food items eaten from June through July coincides with the increased consumption of vegetation at this time. Certain foods such as chironomids, amphipods, and hydracharinids apparently were selected by bluegills in preference to foods such as turbellarians, nematodes, and oligochaetes. Trichopterans and chironomids were two of the more stable food sources for bluegills until late July when abundance of all invertebrate organisms in stomachs diminished. The high abundance of chironomids in May apparently had little effect upon the degree of their utilization.

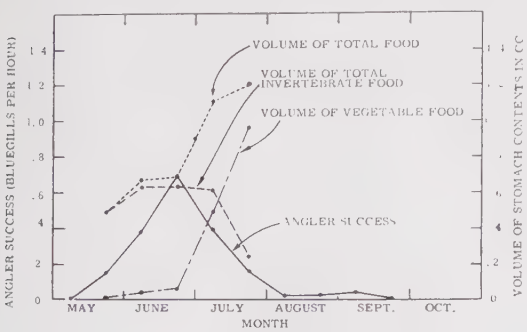

FIGURE 4. — The food intake and the catch per angler-hour of bluegills in Linwood Lake during the 1954 season.

While cladocerans, amphipods, and hydracharinids provided a source of food for bluegills, they varied widely in abundance. As in the case of chironomids, amphipods were not utilized in proportion to their numerical abundance. In July, when there were 84 amphipods per square foot of bottom, an average of only 7 was found per bluegill stomach or about the same number as in May when there were less than 5 per square foot. Although hydracharinids were not sampled with the bottom dredge, the numbers present in stomachs suggested that their abundance was occasionally great although highly variable.

In order to determine the relationship between angler success and gross changes in food intake by bluegills, the catch was compared to relative amounts of animal and plant material taken during the period (Figure 4). Of the two primary food types vegetation

alone appears to be associated with angler success. In July a sharp increase in the selection of vegetation coincided with a rapid drop in fish catch. In the period covered the proportion of animal food in the diet showed no marked relationship to catch rate. Because vegetation formed such a large part of the mid-season bluegill diet, the trend in total food followed the trend of the plant intake. The total food ingested rather than the amount of one type may exert the greatest influence upon angler success, so that when food volume exceeds a certain level the probability of a bluegill taking a baited hook is reduced.

Black crappies.—Stomachs from 156 catchable-size crappies were collected in 1954 and the occurrence of each major group of food organisms was summarized by month (Table 11). Fish present in stomachs were identified to species where possible and fish of the 1954 year class were recorded separately from those of older age groups.

Immature dipterans, primarily chironomids in the pupal stage, comprised the greatest proportion of the insect food. Chaoborinids were of lesser importance than the other midges and the utilization pattern suggests that they were scarce during August. Ceratopogonids formed a significant part of crappie food during the early season. Cladocerans and amphipods were the only other important invertebrates in the summer diet. The number of fish per stomach increased as the season advanced. In June crappies ate some perch from the 1953 year class, but later in the season used young-of-the-year fish. While many fish were hatched in June, they were not large enough to be used extensively for food until mid-July. It appeared that fish about 1 inch in length were the minimum size selected by crappies.

When the percentages of total volume formed by vertebrate and invertebrate food items per stomach were combined by 15-day intervals (Table 12), fish varied from a minimum of 18 percent in late June to a high of 70 percent in early October. While there was considerable variation in food composition following the June low, fish became increasingly important as the season progressed. Fish occurred more frequently in large than in small crappies and the food of some of the largest individuals consisted entirely of fish.

Other workers have shown similar results with fish varying from 15 to more than 50

TABLE 12.—*Fish and invertebrates in the diet of catchable-size crappies in Linwood Lake in the 1954 summer season, expressed as percentage of total volume per stomach*

Date	Number of stomachs	Invertebrates	Fishes
June 1-15	18	35.5	64.5
June 16-30	18	82.0	18.0
July 1-15	27	63.2	36.8
July 16-31	29	35.4	64.6
August 1-15	8	51.0	49.0
August 16-31	5	64.0	36.0
September 1-15	5	44.2	55.8
September 16-30	16	40.0	60.0
October 1-15	16	30.0	70.0

TABLE 11.—*The food of catchable-size crappies in Linwood Lake during the 1954 summer season, expressed as number and percentage of invertebrate animals and number of fish per stomach*

Item	June		July		August		September		October	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Total stomachs	33		56		13		21		16	
Empty stomachs	2		11		0		2		2	
Ephemeroptera	1.7	0.4	1.9	3.1	—	—	1.9	0.8	T[1]	T
Odonata	0.2	T	0.1	0.2			0.3	0.1	0.1	0.2
Hemiptera	0.3	0.1	0.3	0.5			—	—	—	—
Trichoptera	0.5	0.1	0.1	0.2	0.4	0.6	—	—	—	—
Coleoptera	—	—	0.2	0.3	0.1	0.2	—	—	—	—
Chironomidae	32.2	6.9	28.3	46.8	41.3	64.6	21.0	9.3	5.3	8.8
Chaoborinae	7.7	1.6	15.8	26.2			30.3	13.5	19.0	31.4
Ceratopogonidae	9.6	2.0	1.3	2.1	0.7	1.1	T	T	—	—
Cladocera	413.8	88.4	8.4	13.9	12.4	19.4	129.9	57.7	12.9	21.3
Hyalella	0.7	0.2	3.4	5.6	8.7	13.6	41.9	18.6	23.2	38.3
Hydracharina	1.4	0.3	0.5	0.8			T	T	—	—
Copepoda	—	—	0.2	0.3	0.3	0.5	T	T	—	—
Total	468.1	100.0	60.5	100.0	63.9	100.0	225.3	100.0	60.5	100.0
Minnows	0.2		0.4		0.1		—		—	
Sunfish (yy)[2]	—		0.1		0.4		0.4		0.4	
Perch (I-annulus)	0.1		—		—		—		—	
Perch (yy)	T		0.4		0.2		0.5		0.3	

[1]Trace.
[2]Young-of-the-year.

percent of total food volume (Pearse, 1919; Reid, 1950).

The condition factor of crappies, calculated in the manner described for bluegills, showed no definite seasonal changes.

The total variety of food items selected by crappies decreased as the season progressed, but there was a slight increase in numbers and kinds of organisms available. Utilization of fewer items coincided with increased use of chironomids, amphipods, and O-group fish. As in bluebills there was little relationship between apparent abundance of food items and their use (Tables 5 and 11). Selection of chironomids probably did not correspond to apparent abundance because more than half of the midges eaten were in pupal stages, which were free in the water and therefore unsampled. The increasing abundance of amphipods with advancing season coincided with an upswing in selection of these forms.

Selection of forage fish by crappies (Table 11) increased as the prey species became more available (Tables 6, 7, and 8). Since crappies seldom preyed on fish under 1 inch long, the young of some forage species were not eaten in significant quantities until late in the season.

A comparison of angler success with the food intake of crappies (Figure 5) during June, July, and early August showed that there was a reciprocal relationship between total food consumed and angler success. In late August and early September this relationship was not apparent but may have been obscured by small sample sizes. The negative relationship noted between rate of catch over the season and stomach fullness probably was caused to a large degree by the amount of fish in the diet.

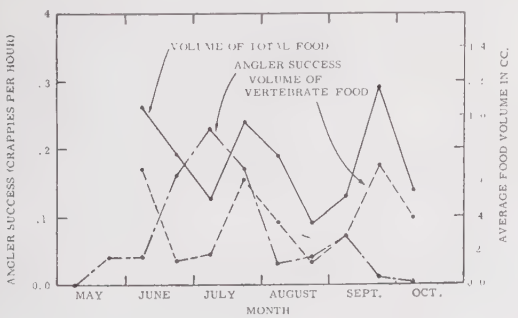

FIGURE 5.—The food volume per crappie stomach and the catch per angler-hour of this species in Linwood Lake during the 1954 season.

It has been shown earlier (Figure 3) that total angling success declined as vertebrate and invertebrate food animals became more abundant in the lake. This relationship existed also when the crappie catch was considered alone.

ANGLER CATCH IN RELATION TO PHYSICAL AND CHEMICAL FACTORS

In an effort to assess the immediate effects on fishing success of some of the more obvious physical and chemical conditions existing in Linwood Lake during the summer season, water temperature, turbidity, hydrogen-ion concentration, dissolved oxygen, carbon dioxide, and total carbonates were measured at approximately bi-weekly intervals and compared with creel census results.

Water temperature

Water temperature varied greatly during the fishing season and in midsummer rose to a maximum of 78° F. at the surface. In May the water was nearly isothermal from surface to bottom. A sharply defined thermocline was established about the middle of June and by early July it was located between the 20- and 25-foot levels. By mid-September thermal stratification had disappeared.

A comparison of seasonal changes in temperature with changes in angler success showed fishing success was poorer following the increase in water temperature and thermocline formation. Fishing failed to improve significantly in September, however, after the water had cooled. While temperature may indirectly affect angling success through its effect on food intake or food availability, the present study did not show that it directly influenced rate of catch.

Turbidity

When turbidity from algal blooms in late summer was highest, angling success was poor. This relationship was not consistent throughout the season, however, and no direct effect was clearly demonstrated.

Chemical factors

Measurements of dissolved carbonates, carbon dioxide, oxygen, and hydrogen-ion concentration were made at different levels in Linwood Lake on 11 dates in the 1954 summer

season. There was no apparent direct relationship between any of these factors and angler success.

CONCLUSIONS

Current management of lake sport fisheries usually assumes that availability of fish to the fisherman remains constant throughout the angling season but creel-census records show that angler success varies widely during the course of a season with the catch generally being highest early in the summer and decreasing as the season progresses. Netting surveys indicate that during this period the abundance of catchable-size fishes varies little or is increased because rapid summer growth speeds recruitment into the fishery. The present investigation was undertaken in 1954 to explore possible causes of this catch pattern in Linwood Lake where survey information and creel-census data were available. Three principal game species, northern pike, black crappies, and bluegills, were included in the study.

A major part of the investigation was concerned with the relationship between angler success and the food of the fish. Estimates of food availability were obtained from analyses of bottom samples and seine catches, and food selectivity was determined from the examination of fish stomachs. A further objective was the determination of the effect of seasonal changes in physical and chemical conditions of the water on angler success. Measurements of water temperature, turbidity, hydrogen-ion concentration, dissolved oxygen, carbon dioxide, and total carbonates therefore were made periodically during the season and compared to catch rate.

Angling success in 1952, 1953, and 1954 was highest in June and early July and lowest in late summer. The rate of catch of northern pike, while never high, increased slightly in the fall of the 1954 season but catch of crappies and sunfish did not rise late in the season. In 1954 the abundance of invertebrate organisms was lowest in June and highest in September and early October. Numbers of young-of-the-year forage fish were greatest in July, but few of them were of a size selected by other fish for food until August. Following the July peak the total volume of young fish continued to increase although their numbers declined.

Angler success for pike was best when the percentage of stomachs containing food was lowest. In May, when the pike catch was relatively high, nearly half of the stomachs were empty. Later in the season when the catch was low, the proportion of empty stomachs dropped. No food other than fish was found in pike stomachs.

Stomach contents of sunfish and crappies indicated that these species were subsisting primarily on invertebrates during the period when angling success was at its peak. At this time abundance of available foods for these species was at the seasonal low.

The average volume of food in bluegill stomachs rose consistently from May through July and more than doubled during that period. Most of this increase was due to the ingestion of large quantities of rooted plant material after July 1. In July the rise in the amount of vegetation taken coincides with a sharp drop in the bluegill catch.

The volume of food in crappie stomachs varied considerably during the season but showed no definite trend. Changes in the total volume of fish ingested by crappies caused much of the variation. The invertebrate food intake, which consisted primarily of immature dipterans, remained more stable. There was some evidence of a reciprocal relationship between total ingested food and angler success in June, July, and early August. Since the change in the proportion of fish in stomach contents accounted for the rise in food volume, intake of fish was probably linked with angler success. In the early season of 1954 crappies were utilizing fish of the 1953 year class. Later, as young-of-the-year fish reached a suitable size, these were selected instead of older and larger fish.

Bluegills and crappies often failed to select items of food which sampling showed were most abundant. This discrepancy may be related to the differential availability of some items, such as burrowing forms, or inadequate sampling of some food items. At times it appeared that fish were selecting scarce food items which in reality were probably abundant.

The findings summarized above lead to several conclusions concerning causes of change in catch rate by anglers during the summer fishing season. Catch per unit of effort declines as the organisms eaten by fish become

more abundant with advance in season. A rise in the average volume of food in bluegill and, to a lesser extent, in crappie stomachs coincides with increased abundance of available food. Changing food supply is therefore believed to bear a reciprocal relationship to changes in rate of catch and to be the principal factor causing seasonal fluctuations in angler success.

Physical and chemical factors exert little or no measurable influence upon angler success during the summer season except as they may influence food production.

ACKNOWLEDGMENTS

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LITERATURE CITED

Ball, Robert C. 1948. Relationship between available fish food, feeding habits of fish and total fish production in a Michigan lake. Mich. State College, Ag. Exp. Sta., Tech. Bull. 206, 59 pp.

Forbes, Stephen A., and R. E. Richardson. 1920. The fishes of Illinois (2nd ed.). Ill. Nat. Hist. Surv., cxxxvi + 357 pp.

Frost, Winifred E. 1954. The food of pike, *Esox lucius* L., in Windermere. Jour. Animal Ecol., 23(2): 339-360.

Hess, A. D., and Albert Swartz. 1941. The forage ratio and its use in determining the food grade of streams. Trans. N. Am. Wildl. Conf., 5: 162-164.

Moyle, John B., and D. R. Franklin. 1953. Creel census of 23 Minnesota lakes, 1952. Minn. Dept. Conserv., Fish. Res. Invest. Rept. 135 (mimeographed), 71 pp.

———. 1954. Creel census of 12 Minnesota lakes, Dec. 1, 1952 to Dec. 1, 1953. Minn. Dept. Conserv., Fish. Res. Invest. Rept. 146 (mimeographed), 35 pp.

———. 1955. Creel census of 12 Minnesota lakes, Dec. 1, 1953 to Dec. 1, 1954. Minn. Dept. Conserv., Fish. Res. Invest. Rept. 159 (mimeographed), 35 pp.

Pearse, A. S. 1918. The food of the shore fishes of certain Wisconsin lakes. Bull. U. S. Bur. Fish., 35: 247-292.

———. 1919. Habits of the black crappie in inland lakes of Wisconsin. U. S. Bur. Fish., Doc. 867, 16 pp.

Reid, George K., Jr. 1950. Food of the black crappie *Pomoxis nigro-maculatus* (Le Sueur) in Orange Lake, Florida. Trans. Am. Fish. Soc., 79: 145-154.

Surber, Eugene W. 1929. The bottom fauna and plankton as food of the smaller slough fishes in the upper Mississippi wildlife and fish refuge. Unpubl. Master's thesis, Univ. Minnesota, 96 pp.

SHORT PAPERS AND NOTES

Selectivity of Food by Brook Trout in a Wyoming Beaver Pond

On September 9, 1952, the dam of a small beaver pond, located on the east slope of the Medicine Bow mountains of Wyoming, was dynamited by the Wyoming Game and Fish Department. A sample of 62 brook trout *(Salvelinus fontinalis)* was collected after the water had drained from the pond (Allen, 1956). Stomachs of the trout were preserved in formalin. Since each stomach had been identified by number, it was possible to compare by age, sex, and size the feeding behavior of brook trout for a single day.

The contents of each stomach were transferred to individual containers and the relative amount of material in each stomach was noted as full, half-full, less than half-full, and empty. Insect food items then were examined under a wide field binocular microscope at a magnification of 15x, and invertebrates classified to order. The number of Ephemeroptera was determined by counting all abdomens with furca. Where adult Coleoptera were present as fragments, two elytra represented one animal. Other items were counted as recognizable individual animals. All material which could not be definitely identified to order was discarded as "debris". However, this debris included many items of food value, such as legs, wings, portions of the abdomen, etc. of various animals, as well as algae, portions of higher plants, and other bulky material. The total length of adult Coleoptera was measured to the nearest millimeter.

The amount of material found in the stomachs was quite large as indicated by the relative fullness of the stomachs (19 full, 25 half-full, 16 less than half-full, and only 2 empty). Apparently the rapid draining of the pond may have dislodged or disturbed the bottom materials of the pond, stimulating the trout to feed actively while the pond was draining.

The frequency of occurrence of food items in the 60 stomachs which were not empty was: Ephemeroptera, 73 percent; Coleoptera, 67 percent; Diptera, 65 percent; Homoptera, Odonata, Plecoptera, Hemiptera, Trichoptera, Arachnida, and Pelecypoda, all less than 5 percent each. The relative quantitative importance of food items was indicated by the total number of recognizable adults and immature items consumed: Ephemeroptera, 322; Coleoptera, 239; Diptera, 233; all others, 23 (Table 1).

A study of the most important food items consumed by trout of different age, sex, and length showed that the relative importance of adult and immature aquatic insects (Ephemeroptera, Coleoptera, and Diptera) varied considerably (Table 1). Immature Ephemeroptera were an important component of the stomach contents of all the trout. Neither adult nor immature Coleoptera were eaten in quantity by the smallest trout (Age 0) but both were important to medium-size trout (Age I and II). The most important items consumed by the largest trout (Age III) were adult Coleoptera and Diptera. No immature Coleoptera were taken by these largest-size fish. Adult Diptera were not eaten by the

TABLE 1.—*Average number of adult and immature Ephemeroptera, Coleoptera, and Diptera consumed by brook trout of different age, size, and sex*

[Maximum number recorded for any one stomach shown in parentheses]

Age	Number	Ephemeroptera		Coleoptera		Diptera	
		Adult	Immature	Adult	Immature	Adult	Immature
0	11	0.0 (—)	6.5 (17)	0.2 (1)	0.3 (2)	0.0 (—)	2.2 (6)
I	23	0.0 (—)	8.3 (68)	1.5 (12)	2.5 (19)	0.3 (16)	3.1 (18)
II	20	0.0 (1)	2.2 (11)	2.3 (18)	4.0 (43)	1.0 (4)	4.2 (41)
III	8	0.0 (—)	5.0 (34)	1.9 (8)	0.0 (—)	1.9 (5)	1.1 (4)
Total	62	0.0 (1)	5.2 (68)	1.6 (18)	2.3 (43)	0.7 (6)	3.0 (41)

smaller trout but were increasingly more important to the larger fish. Immature Diptera were important to trout of all sizes, but they were of lesser importance to the larger fish (Age III).

The increasing importance of mature insects in the diet of the larger trout is shown more clearly by listing the average number of these items consumed by each age class per centimeter of average length (Table 2).

TABLE 2.—*Average number of adult and immature Ephemeroptera, Coleoptera, and Diptera combined per centimeter of trout length*

Age	Mean fork length (centimeters)	Average number	
		Adult	Immature
0	6.7	0.03	1.25
I	10.9	0.14	1.29
II	15.0	0.23	0.70
III	18.6	0.20	0.33

Volumetrically, the importance of the adult insects was much more than indicated in Table 2 because the adult insects were of much larger size than the immature stages.

Change in relative size of food items eaten by different size of fish was examined by plotting the size of adult beetles consumed against length of fish (Figure 1). Beetles were chosen for this study because they were the most numerous adult insect in the diet and because they were easily measured. The beetles consumed by the trout were of two sizes, about 2 millimeters and about 10 millimeters in total length. The smallest trout consumed practically no beetles, either immature or adult, although the small adult beetles were small enough to be ingested. The small size of the trout ages 0 and I precluded their consuming the large beetles. Adult beetles consumed by the 0- and I-aged trout all were of the small size (2 millimeters). Only trout of age II and III ate large beetles; however, of 17 such fish, small beetles occurred in the stomachs of 5 trout. The largest trout in the sample (female, 207 millimeters) contained six of the small beetles. It was possible this fish actually selected the smaller beetles rather than ingesting them involuntarily.

There were approximately 12 fish which seemed to exhibit selective feeding to a noticeable extent. Such fish consumed single food items in disproportionately large numbers as compared with the number of such items consumed by other fish within the same age group. The selective feeding could have resulted by the fish happening to be in a position where the selected item was more available. The rapid draining of the pond, however, should have tended to mix the animals and reduce such localization in food items. No consistent difference in feeding by sex was discerned.

The largest food items found in the stomachs were beetles (Figure 1). No other species

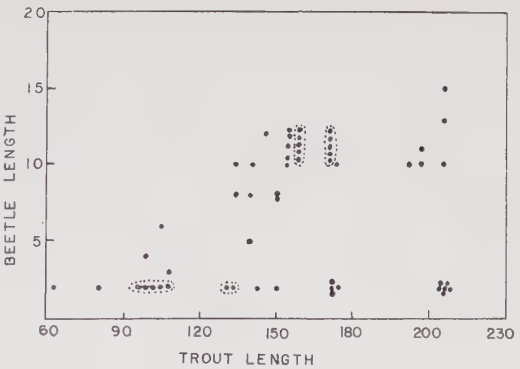

FIGURE 1.—Size of beetles (Coleoptera) consumed by various sizes of brook trout. All measurements are to the nearest millimeter and circled solid areas represent multiple points.

of fish was noted in the pond although the outlet drains into the Little Laramie River where there are numerous forage species. The relatively small average size attained by the older fish might have resulted from the lack of suitable large food items as noted by Allen (1956).

LITERATURE CITED

ALLEN, GEORGE H. 1956. Age and growth of the brook trout in a Wyoming beaver pond. Copeia, 1956(1): 1-9.

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Pike Hybrids (*Esox lucius* x *E. vermiculatus*) in a Sandhill Lake, Nebraska[1]

In the sandhill region of Nebraska both northern pike, *Esox lucius*, and grass pickerel, *Esox vermiculatus*, are abundant in several shallow natural lakes. Both species are known to utilize the same vegetative habitat for spawning during March and April. The pike is an important game species but the smaller pickerel is of little value to fishermen although in winter is at times taken by angling through the ice.

Hybridization in the pike family, Esocidae, has been noted several times in the past. Underhill (1939) and Embody (1918) produced an artificial cross between the northern pike and chain pickerel, *Esox lucius* × *E. niger*. Eddy (1941) reported on hybrids between northern pike and the muskellunge *(E. masquinongy)*. Greeley (1939) observed a cross between the chain pickerel and redfin pickerel, *E. niger* × *E. americanus*. Raney (1957) examined many hybrids of the *niger* × *americanus* cross including back crosses. He found that in almost all instances the back crosses to a parent species were intermediate between the hybrid and the parent species. But it appears from a review of the available literature that a description of the *lucius* × *vermiculatus* cross has not been recorded.

[1]A contribution of Federal Aid to Fisheries, F-4-R, Job No. 2.

EVIDENCE OF HYBRIDIZATION

In several sandhill lakes the grass pickerel attains lengths up to 14.0 inches, although the average size of mature fish is probably around 8.0 inches. The pickerel has been found to mature and enter spawning grounds at 4.0 inches in length. Most male northern pike reach maturity at 18.0 inches in Nebraska and are directly associated with the pickerel during the spawning season. It is not unlikely, therefore, that hybridization could occur if the two species are genetically compatible.

The first probable *lucius* × *vermiculatus* hybrid found in Nebraska was taken during the ice-fishing season of 1958-59. It was caught on hook and line in Watts Lake, a 230-acre lake on the Valentine National Wildlife Refuge. During the ice-fishing season two other hybrids are known to have been caught from this same lake. Several other pike, also reported as "queer" looking, were taken by anglers but were not seen by state fishery biologists. The northern pike population in this lake is mostly of Age II and III fish since winter kill in 1955-56 nearly eliminated older fish.

Trammel and fyke netting on Watts Lake in the early spring of 1959 produced three additional hybrid fish. These fish were netted in conjunction with the northern pike spawn-taking project at the lake. Spawning populations of both species appeared to be high at this time.

TABLE 1.—*Characteristics of four hybrid pike (Esox lucius × E. vermiculatus) from Watts Lake, Nebraska*

Item	Hybrid				Northern pike	Grass pickerel
	Number 1	Number 2	Number 3	Number 4		
Total length (inches)	18.8	19.2	20.0	18.2	—	—
Weight (pounds)	1.9	2.0	2.2	1.4	—	—
Sex	Female	Female	Female	Female	—	—
Sensory pores	5	4	4	5	5	4
Subocular bar	None	None	None	None	None	Present
Branchiostegals (one side)	12	12	13	14	14-16	11-13
Lateral line scales	98	—	120	102	120-125	90-110
Dorsal ray counts	15	16	16	15	14-16	17-18
Body markings	Dark, oblique bars	Dark, oblique bars	Dark, oblique bars	Dark, oblique bars	Light spots	Dark, oblique bars
Cheeks	Fully scaled	Fully scaled	Fully scaled	Fully scaled	Fully scaled	Fully scaled
Opercle	¼ scaled	¼ scaled	¼ scaled	½ scaled	½ scaled	Fully scaled
Age	II	II	II	II	—	—
Gonad development[1]	Immature	Immature	Immature	—	—	—
Distance from tip of upper jaw to center of eye less than twice the distance from center of eye to posterior edge of opercle.						

[1]Histological examinations were not made.

DESCRIPTION OF HYBRID PIKE

Coloration and marking of the Nebraska hybrids resembles closely that of grass pickerel. Alternating dark and light bars extend obliquely forward and ventrally to the lateral margin of the belly. The bars are irregular with slight fuzzing or blotching along the dorsal body surface in two of the specimens. Body color is generally dark. Other characteristics of the Watts Lake hybrids are listed in Table 1.

LITERATURE CITED

Eddy, Samuel. 1941. Muskellunge and muskie hybrids. Minnesota Cons. Vol., 3(14): 41-44.

Embody, G. C. 1918. Artificial hybrids between pike and pickerel. Jour. Hered., 9: 253-256.

Greeley, J. R. 1939. II. The fresh-water fishes of Long Island and Staten Island with annotated list. In: A biological survey of the fresh waters of Long Island. N. Y. Cons. Dept., Biol. Surv. (1938), 13: 29-44.

Raney, Edward C. 1957. Natural hybrids between two species of pickerel *(Esox)* in Stearns Pond. Massachusetts. Suppl. to Fisheries Report for some central, eastern, and western Massachusetts lake, ponds, and reservoirs, 1951-52. Mass. Div. Fish. and Game, 15 pp.

Underhill, A. Heaton. 1939. Cross between *Esox niger* and *Esox lucius*. Copeia, 1939(4): 237.

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Note on Development of Scale Patterns in the Northern Pike, *Esox lucius* L.[1]

Information on the pattern of scale formation was accumulated from 35 northern pike, *Esox lucius* L., during a study of the early life history of pike in a Minnesota lake.

[1]Paper No. 4204 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

The skin from one side (the left, unless that side was damaged) was removed and cleared in a 10 percent solution of concentrated hydrogen peroxide for 10 to 30 minutes. It was then stained with alizarin red in a slightly alkaline solution. Fish less than 30.5 millimeters in length had not started to form scales. Fish between 32.0 and 35.0 millimeters had formed from one-half to one and one-half rows of scales. The first scales form all along the lateral line, with the first row usually appearing below (Figure 1) rather than on the caudle peduncle as in many species. The fish in the 40.0- to 45.0-millimeter range had formed from 6 to 10 scale rows and only the dorsal and ventral midlines were not scaled at 60.0-63.0 millimeters. Complete scalation was noted in fish as short as 66.5 millimeters.

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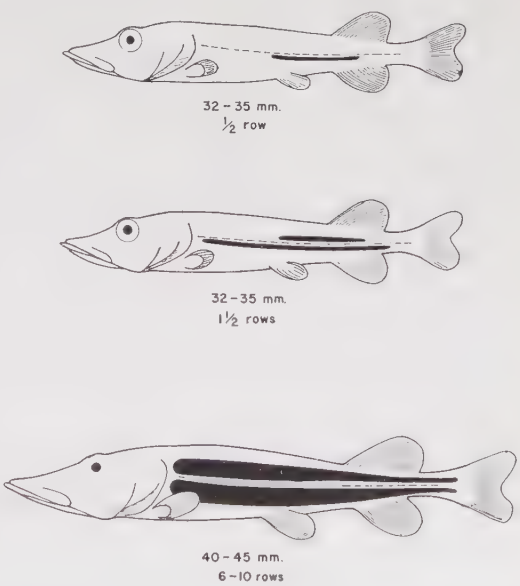

Figure 1.—Location of first scales and approximate advance in scaled area with increasing length.

REVIEWS

AGNATHES ET POISSONS. ANATOMIE, ETHOLOGIE, SYSTEMATIQUE. *Par C. Arambourg et autres. Trois fascicules. (Traité de Zoologie. Anatomie, Systématique, Biologie. Publié sous la direction de M. Pierre-P. Grassé. Tome XIII) Masson et Cie Editeurs, Paris. 1958. 2758 pp, 6 color plates, 1889 figures. 39,000 francs.*

Monumental in scope, this great work effectively crowns some two and a quarter centuries of growth in ichthyology since Peter Artedi (1705-1735). In 2758 pages and some 2000 illustrations (1889 numbered figures; many original) the authors have summarized much of the knowledge of paleontology, classification, anatomy, evolution, genetics, distribution, physiology, and ecology of the largest of the vertebrate groups. In the third volume of the Tome, there are included 63 pages of addenda that eliminate many of the criticisms that a reviewer might have made. These addenda largely make up for omissions and errors in the first two volumes; only a few pertain to the third. If one may presume that the first two volumes were more or less completed before the third, the additions serve well to up-date the bulk of the text. The index to all three volumes has approximately 10,000 entries and covers subject and systematic entities (but not authors of the literature so copiously cited).

The work was prepared under the direction of Pierre-P. Grassé. He was joined in principal authorship by more than 20 other scholars, including Arambourg, Bertin, Fontaine, and Stensiö, among others of outstanding prominence. The review of their effort by Gerd von Wahlert (Copeia, 1958, No. 4) points out a few of the relative weaknesses in treatment of ecology and behavior, especially in food habits and social biology.

The first volume (Premier Fascicule) deals in detail with: the biology of the living lampreys and hagfishes (Fontaine, *et al.)*; the fossil cyclostomes (ostracoderms) (Stensiö); the gnathostomous fishes —skin and skeleton (Bertin), cranium (Devillers), myology (Danois), locomotion (Oehmichen), nervous system (Bertin; Grassé).

The second volume (Fascicule II) contains information on chemical and auditory senses, sound production, the digestive, respiratory, and circulatory systems, air bladder, sexuality and fertilization, and nesting (Grassé), lateral line system (Devillers), cutaneous sense organs of sharks and relatives (Budker), sight (Rochon-Duvigneaud), electric organs (Fessard), blood, plasma, and serum (Fontaine), endocrinology (Vivien), excretory and reproductive organs (Gérard), embryology (Pasteels), viviparity (Budker; Bertin).

Fascicule III contains sections on: larvae and metamorphosis (Bertin); growth, raciation, and migration (Fage; Fontaine); ecology (Bertin); poisonous fishes (Guibé); fish geography (Bertin, Arambourg). A major section treats with fish systematics. Groups (and authors) are: acanthodians (Arambourg); placoderms (Arambourg); chondrichthyans (Arambourg and Bertin); actinopterygians (Arambourg, Bertin, and Lehman); brachiopterygians (Polypteridae) (Daget); lungfishes (Arambourg and Guibé); crossopterygians fossil (Arambourg), living (Millot and Anthony). The last of these accounts is singularly valuable since it contains the best, conveniently available, highly illustrated, original studies of the anatomy of the coelacanth, *Latimeria*, in some 40 pages. Although necessarily superficial in some of its parts, the living coelacanth chapter is strengthened by two handsome color plates and by numerous excellent half-tones. One of the color plates and many of the half-tones of *Latimeria* may be regarded as models of expository photography and serve far better than line drawings to show three-dimensional relationship in anatomy. Millot and Anthony have expanded their treatment of this living fossil in *Anatomie de Latimeria chalumnae* (Centre National de la Recherche Scientifiques, Paris, 1958).

Obviously fishery students and research workers with reading competence in French will find in the present Tome a most convenient source of basic biological information on fishes. They will also find here a quick way into the literature, particularly to non-English European-language papers. In this sense the French work complements beautifully the 1957 two-volume *Physiology of Fishes* edited by M. E. Brown (Academic Press, New York). The bibliographic usefulness of such a work is attested by the growing spread of serial publications carrying information of value to ichthyologists and fishery scientists. Such publications numbered more than two thousand by mid-twentieth century as shown in a count of the journals, etc., listed in the working first draft of *A World Periodicals List for Fisheries Science* (Biology Branch, Fisheries Division, Food and Agriculture Organization, Rome, May 10, 1957).

Of the seventeen Tomes of the Traité as originally conceived, nine have now appeared. Of the six of these that concern the vertebrates, four have been published (XII, embryology, comparative anatomy, and biochemical characteristics; XIII, fish; XV, birds; XVII, systematics and ethology of mammals). Yet to arrive in print are: XIV, amphibians and reptiles; XVI, anatomy and reproduction of mammals. No research or teaching library concerned with fish should lack Tome XIII of the Traité.

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FISH AND SHIPS. *By Ralph W. Andrews and A. K. Larssen. Superior Publishing Company, Seattle, Washington. 1959, 173 pp. 277 figs. $10.00.*

Dedicated "to an inveterate, incurable dreamer . . . an ingrained individualist in a regimented world — the fisherman", this volume provides an excellent historical account of commercial fishing in the North Pacific from the Columbia River to Bristol Bay. Well illustrated with photographs dated as early as 1867, the reader is carried back to the days before the "Iron Chink", when salmon cans were made by hand and dipped in lacquer to prevent rust.

Though not technical, the book is reviewed here because of its historic value and to call attention to the commercial fisherman as an individual, an often neglected fact. This book both documents the progress and development of the fisheries, and recalls the fisherman's struggle with his unique environment.

Emphasis is on the halibut and salmon fisheries but sections are included on the cod fishery, Pribilof sealing, and the whaling industry. The authors have managed an excellent portrayal of vessels and gear. Included are hooks, line, and floats used in the Indian halibut fishing; beach seining with horses on the Columbia River; fish wheels and traps; trolling gear, gill nets, otter trawls, and purse seines; and vessels from three-masted schooners to "smoke boats" to the modern diesel fleet.

Also documented are plant operations, descriptions of canning, fish curing, gear costs, and remuneration to the fishermen (5 cents for a 15-pound king salmon, 1½ cents per red salmon, ½ cent per pink salmon — 1907 gill-netters' agreement). Descriptions of the early years of salmon canning include the first operation in California; handling methods when utilizing Chinese laborers; and the establishment of plants in Alaska.

The reviewers (formerly engaged in Alaska herring research) would have appreciated more detail on the herring industry and fishery, but are cognizant of the limitations necessarily placed on the coverage of the lesser fisheries in the area.

The text is divided into series of short articles, many written in the fisherman's jargon describe personal experiences which provide light, entertaining reading. The reproductions, many dating to the turn of the century, deserve special commendation. As evidenced by the variety of sources, the authors devoted considerable effort to securing photographs most representative of this era.

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A Century of Biological Research. *By Harlow B. Mills and others. Illinois Natural History Survey Bulletin, Vol. 27, Art. 2, pp. 85-234, December 1958.*

Among the biological research organizations of North America that have reached a respectable and respected age, the Illinois Biological Survey is both venerable and vigorous. This 155-page bulletin commemorates and chronicles a century of research carried out by the Survey and its precursors — and looks ahead. The lead article by Harlow B. Mills, the present Chief of the Survey, is a fine bit of biological history. He and his co-workers present a panorama of Illinois biology and its practical problems, beginning with buffalo and passenger pigeons in Cook County and ending with sprayers putting the newest organic phosphorus insecticide on cabbages—DDT no longer gets the cabbage worms. Dr. Mills introduces the early naturalists and entomologists, many of whom were remarkably versatile persons and who accomplished much with little and despite many obstacles. The first two State Entomologists died with their boots on after a few years of one-sided struggle with the hordes of insects that afflicted pioneer Illinois farmers.

It was Stephen A. Forbes, however, who, after his appointment as State Entomologist in 1882, gave real impetus to the wider aspects of biological research. Although Dr. Forbes is best known for his classic, *The Fishes of Illinois*, which he wrote with R. E. Richardson and for that little gem of biological writing, *The Lake as a Microcosm*, he was also well informed and active in many other biological fields. He worked at top speed throughout his long life and, as Dr. Mills notes, was delighted when arrested for speeding on his eightieth birthday.

The contribution of George C. Decker is a fascinating account of past and present battles in the never-ending war with insects. It is interesting to note that biological control — putting a bunch of hungry young hogs in the orchard — was early used to eliminate fruit pests. Dr. Decker concludes that, despite the present effectiveness of organic insecticides, entomologists should again be investigating biological control methods. Herbert A. Ross gives the history of faunistic surveys in Illinois and development of the present extensive collections from the meager beginnings by a few enlightened amateurs a century ago. The many faunistic reports that have been published are listed. J. Cedric Carter does likewise for applied botany and plant pathology.

Dr. George W. Bennett's chapter on aquatic biology is of special interest to fishery workers. He points out that Dr. Forbes was a prime mover in much of the early work and much of it was done at the biological station at Havana on the Illinois River. Here Kofoid made his plankton studies and Richardson worked on bottom fauna. A few members of the Survey who have contributed to fishery knowledge in the more recent period are David H. Thompson, Samuel Eddy, William C. Starrett, Donald F. Hansen, and Dr. Bennett himself. Wildlife research is summarized by Thomas G. Scott, publications and public relations by James S. Ayers, and development of the technical library by Ruth R. Warrick. The format and printing are excellent and the writing uniformly good. The reviewer, as an editor of the *Transactions*, notes with envy that the Illinois Natural History Survey had three technical editors on its staff. The authors with the help of these editors have done a fine job.

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Biological Research in Conservation. *By Arthur B. Meyer and others. In: Bulletin for Medical Research, Vol. 13, No. 1, pp. 4-6, 8-30. January-February 1959. 25 cents.*

It is heartening for fishery and wildlife scientists to receive recognition in a publication of a sister science which has many similar problems. This issue of the *Bulletin* contains five general, but well written and informative articles, on biological research in conservation by Arthur B. Meyer, Carlton M. Herman, Paul E. Thompson, A. L. Nelson, and Durwood L. Allen. Mr. Thompson's article entitled *Fishery Research and Conservation* reviews the progress that has been made and aptly concludes that fishery research "is a growing science with an impressive body of literature but with large and challenging areas of ignorance." Single copies of this special issue are available for 25 cents (less for large numbers) from the National Society for Medical Research, 920 South Michigan Boulevard, Chicago 5, Illinois.

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Recent Publications

Boschung, Herbert T.

The Fishes of Mobile Bay and the Gulf Coast of Alabama. *Thesis (Ph.D.), University of Alabama, University, Alabama. 1957. 626 l., 4 figs., tables.*

Bottemanne, C. J.

Principles of Fisheries Development. *North-Holland Publishing Company, Amsterdam, Netherlands. 1959. xiv, 677 pp. $12.00.*

Duarte-Bello, Pedro Pablo.

Catalogo de Peces Cubanos. *(Laboratorio de Biologia Marina, Monografia 6). Universidad de Villanueva, Marianao, Cuba. 1959. 208 pp. $3.00.*

Hardy, Sir Alister.

The Open Sea: Its Natural History. Part II, Fish and Fisheries, with Chapters on Whales, Turtles, and Animals of the Sea Floor. *William Collins Sons & Co., London. 1959. xiv, 322 pp., 68 plates (part col.), 114 figs., incl. diagrs. and maps. $4.20.*

Hyman, Libbie H.

The Invertebrates: Smaller Coelomate Groups, Chaetognatha, Hemichordata, Pogonophora, Phoronida, Ectoprocta, Brachipoda, Sipunculida, the Coelomate Bilateria. *Vol. V. (McGraw-Hill Publications in the Zoological Sciences). McGraw-Hill Book Company, Inc., New York. 1959. viii, 783 pp., 241 figs. $13.50.*

Templeman, Wilfred.

Redfish Distribution in the North Atlantic. *(Fisheries Research Board of Canada, Bulletin No. 120). Queen's Printer, Ottawa. 1959. 173 pp. 71 figs. $1.75.*

EIGHTY-NINTH ANNUAL MEETING OF THE AMERICAN FISHERIES SOCIETY

Clearwater, Florida

September 16-18, 1959

EIGHTY-NINTH ANNUAL MEETING

AGENDA

Wednesday, September 16

Morning and afternoon: Trips to Lake Apopka, Weekiwachee Springs, and Tarpon Springs.

Evening: Annual banquet in the ballroom, Fort Harrison Hotel, held jointly with International Association of Game, Fish, and Conservation Commissioners.

Thursday, September 17

Morning: Call to order and opening remarks by President Mason Lawrence; determination by Secretary-Treasurer that quorum was present; presentation of guests; appointment of Sessional Committees by the President; report of Secretary-Treasurer; report of Membership Committee; action on nominations for membership; report of Finance Committee; report of Librarian; report of *ad hoc* Committee on Professional Standards and Joint Committee with U. S. Trout Farmers Association; report of chairmen of Regional Divisions and Standing Committees.

Afternoon: Panel discussion on *Estuaries and Their Importance*, presented by D. C. Tabb, John E. Watson, Z. P. Zein-Eldin, E. L. Arnold, Jr., A. Fleminger, and H. B. Simmons, with Seton H. Thompson as moderator. Vice-President James W. Moffett presided. Presentation and discussion of papers.

Evening: Presentation and discussion of papers.

Friday, September 18

Morning: Panel discussion on *Management of Natural Lakes*, presented by John Greeley, Melvin T. Huish, Jerome Kuehn, Norman Benson, and O. L. Wallis, with Ed Hueske as moderator. Vice-President Carlander presiding. Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; concluding business session; reports of Sessional Committees; election of officers; installation of new officers; concluding business.

BUSINESS SESSIONS

Opening Business Session

The eighty-ninth annual meeting of the American Fisheries Society convened in the Hibiscus-Colonial Room of the Fort Harrison Hotel, Clearwater, Florida, September 17, 1959. The meeting was called to order by President Mason Lawrence who presented the following remarks:

There is certainly no scarcity of challenging subjects this year. However, in considering what I might properly report to you on, I came to the conclusion that perhaps there was nothing more important to us as members of the Society than the activities of the Society. I shall, therefore, report to you very briefly on the activities during the past year with the hope that this information will provide a general background for the more detailed reports of the other officers and committee chairmen that will follow.

This has been a busy and eventful year for your Society. In addition to the routine operations involved in serving some 2,000 members, we have had the challenge of implementing the significant actions voted at the last annual meeting. We have also taken action in certain areas in an attempt to improve the services of the Society to its members and to the fishery field generally.

Each of you has received two issues of the quarterly *Transactions* and may expect to receive the third issue shortly. The change from an annual to a quarterly publication was voted by the members last year and was accomplished with a minimum of delay due to the tremendous efforts of our editor and the fine cooperation of the editorial board. A special committee consisting of Drs. Gerald Cooper, Ralph Hile, and Robert Miller rendered a valuable service to this Society in advising on the format of the quarterly.

The Society has published during the past year a career guide entitled *Fisheries as a Profession.* As indicated by the demand for this publication, it has been well received and is serving a useful purpose in acquainting students with pertinent information on the fisheries field.

We had hoped to publish during this calendar year a revised and expanded list of the common and scientific names of fishes. It appears that this will not be possible, but this publication will be forthcoming shortly in the new year. Those of you who have had the opportunity to review the preliminary draft of this revision know of the very fine job that Dr. Reeve Bailey and his Committee on Names of Fishes have done.

I am happy to announce also that the *Technical Writers Handbook,* a joint publication of this Society and the Wildlife Society, will be available shortly. This fine handbook was written by Werner Nagel of the Missouri Conservation Commission, with the assistance of a committee composed of two members from each of the sponsoring societies, that is, the Wildlife Society and the Fisheries Society. The publication of the handbook incidentally is being financed by a grant from the American Conservation Association.

Just a couple of comments on finances. The response to the increase in membership dues has been gratifying, in my opinion. We have lost some members, as we anticipated. I believe, however, that we have retained a majority, a great majority of the interested and potentially active who are the strength of any society. Your Finance Committee made a very thorough study during the past year of the investments of the Society and recommended to the Executive Committee at its meeting on March 2 in New York (1) that we retain our government bonds to maturity, and (2) that we convert our common stocks into a mutual fund investment. The Executive Committee approved these recommendations and the common stocks have been converted to a mutual fund investment.

I would report to you also that the Executive Committee at its meeting in March voted to pay the Secretary-Treasurer an annual stipend of $1,000, effective from March 1, 1959. I am sure all of you know how much that has been earned.

I would like to make a couple of comments, too, on division meetings. Each of the divisions of the Society has had a successful meeting since our last annual meeting. I had the pleasure of attending the meetings of the North-Central and the Northeastern Divisions. I had planned to attend the Southern Division but unfortunately a last minute change of my schedule within my own department made that impossible. From my experience I should suggest to the Society that it encourage its president to attend the meetings, annual meetings of all divisions. His attendance would provide an opportunity to bring the activities and problems of the Society to many more of the members and, equally important, would give the President an opportunity to become more familiar with the thinking and wishes of the membership. The over-all effect would, in my opinion, be to strengthen greatly the ties between the Society and the many members who cannot attend annual meetings regularly.

I should call your attention to the special reports which will be given later this morning.

the report of the special Committee on Professional Standards and the report of the special Joint Committee with the U. S. Trout Farmers Association. Both of these committees were created at your request and have devoted a great deal of work to their assignment. I should ask, therefore, that you give careful attention to their reports and recommendations.

In closing, I should like to list for you several proposals which have been made and which I believe may be the subject of future consideration by the Society.

1. As one well known to us, the desirability of establishing a full-time Executive Secretary.

2. The desirability of combining the offices of Librarian and Secretary-Treasurer.

3. The desirability of contracting with an outside agency for some of the routine functions involved in the work of office of Secretary and Treasurer, Librarian, and Editor.

4. The desirability of establishing joint executive-secretarial and editorial services with some other society, such as the Wildlife Association or the International Association.

5. The desirability of charging a registration fee for the annual meeting.

6. The possibility of establishing membership dues at a lower rate for persons not professionally employed in the fisheries field but who are interested in retaining membership in the Society.

7. The possibility of changing the membership year from the present fiscal year to a calendar year or some other type of year, and incidentally, in this connection, with the quarterly billing on the present fiscal year, it is rather awkward.

Time does not permit a discussion of these proposals here. I merely list them in hope that you will give them careful thought in the event that any of them should seriously come before you in the future.

I want to express my personal thanks to you for the privilege of serving you as an officer for the past 3 years. It has been a wonderful experience and one that I shall always cherish.

A quorum was determined to be present by the Secretary. Guests were introduced including Herminio R. Rabanal, Philippines; Yoel Pruginin, Israel; Zaynul Abedin, Pakistan; Seung Kwan Chun, Korea; and Ul-Bae Kim, Korea.

President Lawrence then appointed Sessional Committees as follows: *Nominating Committee* — John Gottschalk, *Chairman*, Leo Shapovolov, E. B. Speaker, W. J. Fry, and Eugene Surber; *Time-and-Place Committee* — John Funk, *Chairman*, Richard Whiteleather, Charles Bower, Gustave Prevost, and Al Houser; *Resolutions Committee* — Albert Swartz, *Chairman*, Kenneth Loftus, J. Frances Allen, Saul Saila, and Robert Meigs; *Auditing Committee* — William Hassler, *Chairman*, Wayne Seaman, and Earl Rose; *Publicity Committee* — John Dequine, *Chairman*, Leonard Foote, Ed. Hueske, and Charles Schilling.

Secretary Seaman presented the Secretary-Treasurer's report, pointing out especially the problems and increased load of the Secretary's office. Increased revenues, largely from higher membership dues, were received during the year. The Secretary's office prepared a new membership application and a descriptive brochure, and placed an advertisement of the new quarterly *Transactions* in the *Bulletin* of the American Institute of Biological Sciences. Part of the increased load of the Secretary's office is occasioned by more frequent issues of the *Newsletter*, the answering of questionnaires, and the supplying of information to the membership. Response to the *Newsletter* has been very favorable. A special accomplishment of the Secretary's office was the preparation of a brochure, *Fisheries as a Profession*, which has been widely distributed in educational fields. Mr. Seaman moved the Secretary's report be accepted. The motion was seconded by E. B. Speaker and carried. Richard T. Whiteleather commented favorably on the activities of the staff of the Society and on the success of the brochure on professional fishery biologists' functions.

James W. Moffett presented the report of the Membership Committee as follows:

The work of the Membership Committee of the American Fisheries Society during the past year has centered on two objectives: (1) the holding of members in the Society, and (2) the solicitation of potential members by libraries, institutions, and other organizations which might profit from subscription to the Society's journal. The Membership Committee as a group has functioned very well. All of the members appointed have been active and practically all of them have put forth individual effort to solicit interest and applications from people in their assigned territories.

This report was written as of August 25 and I have another score sheet from the Secretary that is more recent, so I shall talk from it in giving you the statistics covering the acquisition and loss of members during the past year.

During the year since the Philadelphia meeting, we have picked up in all classifications 252 members. We have had a loss by resignation, deaths, dropped for non-payment of dues, etc., of 273 members. The net loss then is 21.

The classification of members who have entered the Society in the past year goes something like this: 134 active members; 12 foreign

members; 63 student members; 2 from the military; 3 sustaining members; 23 libraries; and 1 official membership. This does not add up to the 252 because 4 former members were reinstated, and the breakdown was made on the previous situation which involved only 242 persons. At the present time we have on our rolls 2,075 individuals or institutions. These are classified as follows: active, 1,619; student, 119; foreign, 44; military, 9; sustaining, 30; official, 48; library, 136; life members, 47; honorary members, 13. They add up as a discrepancy here because 10 members are not classified in this breakdown.

My original report stated that the Membership Committee feels rather proud of the total. I must alter that because we feel somewhat chagrined at the loss of 21 members in the net campaign. The Committee, however, has had extensive contacts, both personal and by mail, in practically every district in the United States and Canada. Individual committee members have sent from 50 to 300 letters to persons or institutions calling their attention to the value of the Society and urging them to join. In one case a committee member contacted each present member and all past members in the seven states for which he was responsible. These persons were asked to show their interest in the Society by continuing membership and by working toward the recruitment of new members. These people were also advised that illustrative material and informational leaflets were available for distribution. One member advised that the Southern Division had a Membership Committee of its own and stated that through his efforts and that of the Southern Division many people had been contacted twice, so his job had really been thoroughly done.

The Committee Chairman wishes to express his deep gratitude to all members of the committee and his appreciation for the frequent and effective advices from the Secretary of the Society. These communications kept us informed on the number and kinds of members entering the Society.

Dr. Moffett moved that the report be accepted. The motion was seconded by H. S. Swingle and carried.

The President called for nominations of new members. Secretary Seaman proposed a list of 252 names for admission to new membership and moved that they be accepted without formal reading on the basis of an authorized list prepared by the Secretary and properly filed with the Society records. The motion was seconded by John Funk and carried.

The President called for nomination for honorary memberships in the Society and pointed out that election required unanimous approval. James Moffett presented the name of Talbott Denmead III, with the following remarks in support of the nomination:

It is my deep pleasure to offer the name of Talbott Denmead III for consideration to honorary membership. The President has been furnished with the properly executed petition signed by the requisite number of members. Talbott Denmead is a distinguished citizen of Maryland. He has been a member of the American Fisheries Society for many years, acted ably in various administrative positions in Wildlife Conservation in Maryland, and in the U. S. Fish and Wildlife Service, who is now retired from active duty, and who carries with him an outstanding record of achievement.

Dr. Moffett moved the election of Talbott Denmead, the motion was seconded by John Gottschalk, and carried. In support of his second Dr. Gottschalk remarked:

I think many of us who have been members of the Society for several years will recall that Talbott began his career in the very early days and was one of the primary instigators, you might say, and active people in the development of the Black Bass Act and was sponsoring carrying out the provisions of the Black Bass Act at the time that the law was enacted. Since then he has maintained a very active interest in all forms of fishery conservation work. His most recent assignment has been in the State of Maryland where he was the editor of the Maryland Fish and Game magazine. It was only the forced removal of the Maryland Department from Baltimore to Annapolis that caused him ultimately to drop out of the active ranks, closing a career that, I am sure, goes back something like four decades in fishery work.

[Ed. Note: Two more honorary members were proposed during the closing business session, page 95.]

President Lawrence called for the report of the Finance Committee. George J. Eicher presented his report, which treated in detail the investment of funds and the problem of establishing a position of Executive Secretary. In commenting on the contents of his report, Mr. Eicher said:

In the last few days we have discovered a number of factors that have come upon us principally since this meeting has gotten under way. I have discussed this matter with the Secretary, President Lawrence, Edward Schneberger, and many of the other members present here.

One thing that has been of particular interest is the fact that many of us now have serious doubts that we could finance an executive-secretary position on a $5-increase. It seems out of the question to do so. The Finance Committee has apparently been remiss in not going into the background of this thing as much as we should have. I was under the impression that there was some research done to determine the $15-figure, but apparently no great amount had been done. It was just a figure that was picked out of thin air. I understand there was some thought that

it would finance the Executive Secretary with a yearly salary of some $8,000. I think if we were going to hire one for $8,000 we'd possibly be wasting our money. We need a man of rather high calibre that could not be attracted by that low a figure.

What I am getting to is this: that it seems even more pressing that this thing be studied a great deal more than has presently been done before we go into any such increase or any such position.

I might also add that we are not alone in this matter. I think the AIBS certainly is. We know the Wildlife Society is in the throes of the very same thing at the moment. There are other organizations that are doing the same thing, and it may pay us while we are studying it to note what they are doing, and perhaps be guided by some of the decisions they make.

Mr. Eicher moved that the report be adopted. John Greeley seconded the motion, which was carried.

The President called for the report of the Librarian. Howard A. Tanner presented his report, pointing out that the advent of the quarterly publication has greatly increased the work of his office. A total of $1,815.75 was forwarded to the Secretary's office from the sale of old volumes and special publications. The Librarian moved the report be accepted. The motion was seconded by Richard Whiteleather and carried.

Raymond E. Johnson presented the following report of the Special Awards Committee:

The idea for presenting an award to an American Fisheries Society member began with an Executive Committee meeting in St. Louis in March 1958. A special committee was appointed then by President Swingle to organize an award system for the most interesting paper and the best presentation at the annual meeting.

The special committee concluded that awards, perhaps at both the division and national levels, could be based on the best papers presented at the annual meetings. It was hoped that this recognition would recruit outstanding fisheries papers for the annual meetings at both levels, would encourage publication of research findings in the *Transactions*, and would provide recognition for outstanding written contributions to fisheries science by members of the American Fisheries Society.

It did not prove practical to judge manuscripts prior to a meeting or to give careful attention to papers as they were presented. Furthermore, an award restricted to Society members who can attend a meeting would have discriminated against the majority of members who must remain at home. Therefore, the special committee tried to arrange for the selection of the "best" paper in the last complete volume of the *Transactions*.

A small group of well-qualified Society members served as judges of all papers in the last complete volume of the *Transactions* (volume 87). They first established criteria for the judging so that all reviewers regardless of their inclinations could evaluate the papers somewhat alike. The aim was to find a common basis for rating the papers without regard to subject, whether they discussed salmon or shad, taxonomy or ecology, management or research, laboratory or field work, or a local or nationwide scale. Attention of the reviewers was directed to a paper's character rather than to its subject by means of several questions:

1. Does the paper display results of original research or creative thinking by the author?
2. Is pertinent literature well covered, the study well planned and executed, the conclusion fully documented?
3. Is the paper clearly written and are the graphic data logically presented?
4. Would the study and the paper serve as a model for a student, and would its result contribute facts and ideas to a professional colleague?

When the papers were examined in the light of these questions, they began to rank themselves in the minds of the reviewers in a definite order. Lowest ratings were given to papers reporting an isolated event or a fact of local significance or a new technique of limited use. Higher ratings were given to reports of more complex studies which involved several lines of investigation. Still higher rank was accorded papers which contained correlations of data from diverse but related research efforts. At the top were papers reporting on studies which not only planned and executed several lines of work and correlated the findings, but also developed new research techniques of broad application, or resulted in a major new fish management method or research principle.

After considering the 37 papers in Volume 87 and narrowing the choice down to about eight, and then examining those still more closely, the reviewers chose one which seemed to be the best of the field.

The paper that the reviewers thought deserved the reward was titled, *Size Limits in Largemouth Black Bass Management*, by Dr. Saul B. Saila of the University of Rhode Island.

President Lawrence presented the award to Dr. Saila together with a check for $50.

Reports of chairmen of the Regional Divisions were then called for.

I. B. Byrd presented the report of the Southern Division as follows:

The last meeting of the Southern Division was held in Louisville, Kentucky, last October. Approximately 120 persons attended the technical sessions. The meeting was held, as usual, in conjunction with the Southeastern Association of Game and Fish Commissioners. A total of 19

technical reports on fisheries and related subjects were presented. The fishery reports given at the Southern Division Meeting are published in the *Proceedings of the Twelfth Annual Conference, Southeastern Association of Game and Fish Commissioners.* Copies of the *Proceedings* can be obtained from member states or from Mr. J. W. Webb, Secretary, Southeastern Association of Game and Fish Commissioners, South Carolina Wildlife Resource Department, Columbia, South Carolina. The *Proceedings* are usually printed and available for distribution by July following the October meetings.

Important resolutions passed at the October 1958 meeting included the following: (1) Recommend that the American Fisheries Society hire a full-time Executive Secretary who would devote considerable time to the vitally important matter of professional classification looking toward accreditation; (2) Recommend to the Society to increase the annual dues for active members to not less than $15 annually to permit employment of an Executive Secretary. I believe that it is the feeling of the southern members that we are getting excellent service for the money that we are now paying, but in order for us to get additional services, we must pay. Apparently that is their feeling, and I believe that that pay would not be worth Confederate money. I think that is safe in case the South should rise again. The rest of the resolutions were as follows: (3) To create and establish a committee on reservoirs; (4) To create and establish a subcommittee on pollution; and (5) Recommend that the American Fisheries Society at its 1959 meeting take such action as necessary to transfer the State of Maryland from the Northeastern to the Southern Division.

The next annual meeting of the Southern Division will be held at the Emerson Hotel, Baltimore, Maryland, during October 25-27, 1959. Mr. Edwin M. Barry of the Maryland Game and Inland Fish Commission is Program Chairman.

Mr. Byrd moved the adoption of the report. It was seconded by John Dequine and carried.

The Northeastern Division report was presented by Saul B. Saila as follows:

The 1959 meeting of the Northeastern Division was held under the chairmanship of Dr. Edward C. Kinney on April 19-22 at Oglebay Park, Wheeling, West Virginia. Half-day sessions were devoted to panel discussions on marine and estuarine studies and fish management in reservoirs. Quarter-day discussions were held on the use of fish toxicants and the philosophy and administration of aquatic weed control. One-half day was devoted to miscellaneous fishery papers.

The 1960 Northeastern Division meeting will be held on January 10-13 at the Sheraton-Biltmore Hotel, Providence, Rhode Island. Saul B. Saila, University of Rhode Island, is the chairman; Lyndon A. Bond, Maine Department of Inland Fisheries and Game, is the vice-chairman; and James P. Galligan, Connecticut Board of Fisheries and Game, is secretary and treasurer. The general theme of the 1960 meeting will be *Improving Liaison Among Conservationists.* Emphasis will be placed on the coordination of the efforts of the various conservation agencies toward the solving of more important problems and improving the exchange of ideas and information.

Dr. Saila moved that the report be accepted. It was seconded by George Rounsefell and carried.

John Funk presented the following report of the North-Central Division:

The third annual meeting of the North-Central Division of the American Fisheries Society was held at Columbus, Ohio, December 15-17, 1958, in conjunction with the Midwest Wildlife Conference. The fisheries sessions of this conference constitute in fact the technical sessions of the North-Central Division meeting, although, in keeping with the informal nature of the Midwest, they are not so designated. An excellent program of papers was presented. President Lawrence, Secretary Seaman, and Editor Moyle addressed the group of about 100 members present for the business meeting. In addition to the chairman, Robert E. Schumacher of Minnesota was elected vice-chairman and Orty E. Orr of Nebraska was reelected secretary.

In addition to the Division meeting, a number of other fisheries meetings were held in the North-Central's area and are of interest because the participants usually are Society members. The fifteenth annual meeting of the Upper Mississippi River Conservation Committee was held in Chicago on January 6, with 32 representatives from Illinois, Iowa, Minnesota, Missouri, Wisconsin, the U. S. Fish and Wildlife Service, and the U. S. Army Corps of Engineers in attendance. The Fish Technical Subcommittee discussed a continuing fisheries survey of the river. The committee also sponsored a Fishing Gear Clinic which was held in Lansing, Iowa, June 3 and 4, with 30-odd individuals from the participating agencies in attendance.

The Tri-State Fisheries Conference includes fisheries men from Michigan, Minnesota, and Wisconsin. The fifteenth annual meeting was held in St. Paul on January 14 and 15. One hundred thirty-one delegates from the three states, the U. S. Fish and Wildlife Service, and the Great Lakes Fishery Commission attended a series of informal panel discussions of fishery management problems.

Ohio also participates in an informal Tri-state Meeting with West Virginia and Kentucky. There may be other such meetings which have not come to my attention but I believe this is sufficient to show that the fishery men in the North-Central Division are an active group.

Dr. Funk moved that the report be accepted. It was seconded by Lee S. Roach and carried.

George J. Eicher presented the following report of the Western Division:

The eleventh annual meeting of the Western Division of the American Fisheries Society was held at Portland, Oregon, in conjunction with the thirty-ninth annual meeting of the Western Association of Game and Fish Commissioners on June 29-30 and July 1, 1959. Dr. John Rayner, program chairman, arranged a very pertinent and extensive program for the technical sessions. One panel session dealt with fish nutrition work on both trout and salmon. The second session covered topics of fresh-water fisheries management with special reference to new techniques and equipment. Fisheries problems of the Columbia River drainage received special consideration on the program. Facilities provided for the meeting were excellent, adding comfort, pleasure, and value to the presentations of the technical sessions. Though the sessions were extremely busy ones, the afternoons passed all too quickly. Approximately 150 persons attended the technical sessions each afternoon.

Mr. Eicher moved the report be accepted. It was seconded by Eugene Surber and carried.

After an intermission the President called the attention of the Society to the interest which has been shown in the problem of professional standards for fisheries biologists, and to the fact that an *ad hoc* committee headed by Lloyd L. Smith, Jr. was appointed at the eighty-eighth meeting to explore the problems involved in the setting of professional standards. Dr. Smith presented the committee report and emphasized the necessity for defining accurately a fishery biologist and the problems involved in setting standards, accrediting teaching institutions, and setting up codes of ethics. The Committee recommended acceptance of its definition of a fishery biologist and the continuation of committee work. Dr. Smith moved that the Committee report be accepted. It was seconded by Percy Viosca and carried.

H. S. Swingle presented the report of the joint *ad hoc* committee between the American Fisheries Society and the U. S. Trout Farmers Association, and moved that it be accepted. The motion was seconded by J. H. Cornell and carried.

The President called for the reports of the Standing Committees. In the absence of Norman S. Baldwin, John Gottschalk presented the report of the Committee on International Relations. He moved the adoption of the report. It was seconded by Ross Leonard and carried.

The report of the Editorial Board was presented by the Editor, John B. Moyle, who moved its adoption. It was seconded by Clarence Tarzwell and carried.

Richard Whiteleather expressed surprise that it was necessary to build up a back-log of papers for the quarterly since it had been assumed that a major problem was the publication of available material. President Lawrence called for a standing ovation for the services of Dr. Moyle who was responsible for launching the quarterly.

Reeve M. Bailey presented the report of the Committee on Names of Fishes and pointed out that it would soon be available in printed form for distribution but could not be presented in its entirety at this meeting. He moved the adoption of the report. It was seconded by Alex Calhoun and carried.

The report of the Committee on Water Pollution was presented by Clarence Tarzwell, who moved its adoption. Gordon Gunter seconded the motion, which was carried.

In the absence of Edwin S. Iversen, chairman of the Committee on Commercial Fisheries, the report was presented by Richard Whiteleather, who moved its adoption. The motion was seconded by H. S. Swingle and carried.

The report of the Committee on Hydrobiology and Fish Culture was presented by I. B. Byrd, who moved its adoption. After a second from the floor, the motion was carried.

Following the conclusion of the final committee report, the meeting was adjourned at 12:30 p.m.

Closing Business Session

The concluding business session of the Society was called to order by President Lawrence at 3:10 p.m., September 18, in the Hibiscus-Colonial Room of the Fort Harrison Hotel, Clearwater, Florida. After opening the meeting the President extended the thanks of the Society to the Program Committee in charge of the eighty-ninth annual meeting and then called for the report of the Time-and-Place Committee. It was presented by John L. Funk as follows:

> The report of the Chairman of the Time-and-Place Committee on odd-numbered years is a vestigial structure with no more practical function than the adipose fin or the pyloric caeca. Everyone has known what he is going to say since day before yesterday, the whole thing is merely empty form. However, let us maintain proper form, by all means, for on even-numbered years the announcement by the Chairman of this committee is followed with breathless attention.
>
> The Time-and-Place Committee of the International Association of Game, Fish, and Conservation Commissioners and of the American Fisheries Society met in joint session to consider invitations from a number of different states which offered their hospitality to the two organizations for their 1961 meetings. First, let me remind you that the 1960 meeting will be held on September 12-14 at the Denver-Hilton Hotel in Denver, Colorado. Following long established custom, the American Fisheries Society will hold its meetings on Monday and Tuesday, Wednesday will be reserved for tours and conviviality and the International Association meeting will be held on Thursday and Friday.
>
> The recommendations of your committees for the site of the 1961 meetings were made after careful consideration of the locations of meeting places during recent years, the convenience of travel to the locality in question for the bulk of the membership of the Society, and the benefit to the conservation program in the region which might result from the meetings. Since the year is odd-numbered, the committee jointly recommended that the International Association meet on Monday and Tuesday, September 11 and 12, and that the American Fisheries Society meet on Thursday and Friday, September 14 and 15, with Wednesday devoted to joint activities to be scheduled by the two program committees.
>
> Your Time-and-Place Committee recommends that the 1961 meetings of the two organizations be held in Memphis, Tennessee.

The following report of the Auditing Committee was presented by Wayne R. Seaman:

> The Auditing Committee has examined the accounts and the records of the Society for the fiscal year 1958 and 1959 and found them to be in good order. The committee also examined the report of Howard C. Haire, Certified Public Accountant, of Rockville, Maryland. This report, dated August 13, 1959, states that the accounts of the Society are correct. The Auditing Committee also wishes to commend the Secretary-Treasurer for the excellent manner in which he has conducted the business of the Society.

Kenneth Carlander moved the adoption of the report. It was seconded by Percy Viosca and carried.

Albert S. Hazzard placed the name of Fred A. Westerman in nomination for honorary membership with the following comment:

> It gives me great pleasure to offer a petition which bears the requisite number of names, placing in nomination for honorary membership Fred A. Westerman of Lansing, Michigan. He was born at Paris, Michigan, in 1890, joined the predecessor agency of Michigan's Fish Division in 1913; progressed through the ranks from laborer to fish-car superintendent to hatchery superintendent to division chief, a position he filled with distinction for 34 years; served as president of the Society in 1934 and throughout his long career was always available for arduous and responsible service to the Society; was an outspoken supporter of research and a recognized leader in the development of the scientific approach to fish management; was constantly interested in the professional growth and advancement of younger members of the field; and throughout his 46 years of active service demonstrated a degree of personal integrity and devotion to duty representative of the highest ideals of public service.

The nomination was seconded by Edward Schneberger and was unanimously approved. Mr. Westerman accepted the election and stated that it was the highlight of his service in the state and with the American Fisheries Society.

Lee S. Roach presented the nomination of Edward L. Wickliff for honorary membership with the following remarks:

> I have the honor to offer for nomination for honorary membership in the American Fisheries Society the name of Edward L. Wickliff, and present the petition with the requisite number of signatures. Edward L. Wickliff was born in the city of Columbus, Ohio, and is a graduate of Ohio State University with both bachelor and master's degrees, teacher at the University for several years and actively and immediately associated with the Ohio Division of Wildlife since 1922 as Chief of the Bureau of Scientific Research and later as Chief of the Section of Fish Management, during which years he also represented that agency on state legislative matters pertaining to fish, game, and conservation, member of the American Fisheries Society for over 35 years, active on many of its committees and

president in 1934-35, member of the Ohio Academy of Science, the American Association for the Advancement of Science, American Society of Limnology and Oceanography, Midwest Wildlife Conference, and several other scientific and professional groups, author of many scientific and popular papers, member of the Izaak Walton League and other local fish, game, and conservation organizations.

The nomination was seconded by Ralph Hile and unanimously approved.

Albert H. Swartz presented the report of the Resolutions Committee.

Resolution No. 1—Registration Fee at Annual Meeting

WHEREAS, it is customary for many professional societies to charge a registration fee, and

WHEREAS, it seems fair that those who attend the annual meeting bear the costs, and

WHEREAS, it has been estimated that a registration fee of not more than $5 would cover the cost of such a meeting, and

WHEREAS, a poll by mail of the membership showed an overwhelming majority to be in favor of such a fee; now, therefore,

BE IT RESOLVED, that the Bylaws of the Society be amended by the addition thereto of a new Section 25, Registration Fee, to read as follows: "The executive committee is authorized to establish and charge a registration fee not to exceed $5 for each person in attendance at the annual meeting."

Mr. Swartz moved the adoption of the resolution. It was seconded by Ralph Hile. John Dequine suggested that some people might not feel free to register if there was a fee, and that the needs of the meeting should be taken into consideration before setting the maximum fee. H. S. Swingle recommended that students not be charged a registration fee. Seth Gordon thought the proposed amendment was ambiguous and George Rounsefell suggested that it be amended to apply only to members in active standing. President Lawrence stated that the Executive Committee had discussed the problem and chosen the word "person" to permit flexibility in the action of the Executive Committee. The resolution was put to a vote and carried.

Resolution No. 2—Reinstatement of Members

WHEREAS, Section 9 of the Bylaws requires that any member who has forfeited his membership may not be re-elected as a member unless he has paid all back dues and has paid dues for one additional year in advance, and

WHEREAS, if enforced, as it has generally not been, few individuals would rejoin, particularly under conditions of higher dues; now, therefore,

BE IT RESOLVED, that the following revision in Section 9 be made: in line 1, change "for a period of more than one year" to "for a period of one fiscal year"; delete the entire second sentence and substitute: "Any member who has forfeited his membership through nonpayment of dues may be re-elected as a new member." Section 9 will then read: "Any member who fails to pay his dues for a period of one fiscal year shall be given written notice by the Secretary-Treasurer that his name will be removed from the membership list unless back dues are paid in full within 60 days from the date of such notice. Any member who has forfeited his membership through nonpayment of dues may be re-elected as a new member.

Adoption was moved by Mr. Swartz and seconded by Robert M. Paul. J. H. Cornell asked if reinstatement of a member would make him eligible to receive all past copies of the *Transactions*. President Lawrence stated that under the policy already in effect back volumes would be made available only on payment for same. The resolution was put to a vote and carried.

Resolution No. 3—Revision of Bylaws pertaining to Water Pollution Committee

WHEREAS, Section 18 of the Bylaws requires that the membership of this committee be named by the Nominating Committee and elected by the membership, and

WHEREAS, the same section establishes a membership of seven individuals, and

WHEREAS, effective attainment of the objectives of this committee calls for detailed and continuous knowledge and experience in all matters affecting pollution including research, abatement, and legislation, and

WHEREAS, these requirements can be attained only by continuity in tenure, uniformity in geographic coverage, and assignment of smaller areas to individual members; now, therefore,

BE IT RESOLVED, that Section 18 of the Bylaws be amended to delete the last sentence and substitute therefor the following: "The committee shall consist of members in good standing who shall be recognized specialists in the water-pollution field and familiar with pollution problems in the several regions of North America, who shall be appointed by the President."

Mr. Swartz moved for adoption of the resolution. The motion was seconded by Clarence Tarzwell, who pointed out:

> In carrying on the work of this committee, we have found that it is a good deal of work for an individual who has a large area to cover. Some of those committees have suggested that the areas assigned to them should be smaller so that the task would be less and so that they would be assigned an area with which they were acquainted and would know whom to contact in

regard to research work. Since we are contacting not only water pollution control boards, state health organizations, and conservation departments, but also universities and private organizations carrying on research, it is desirable to have the individual well acquainted with what is going on in his area. In the past we have sometimes had certain individuals who have been assigned areas with which they were not acquainted, so that the increase in the number of the committee and appointment according to geographic areas seems to be indicated by past experience.

The resolution was put to a vote and carried.

Resolution No. 4 — Revision of Bylaws pertaining to Committee on Names of Fishes

WHEREAS, Section 15 of the Bylaws provides that the membership of this committee be named by the Nominating Committee and elected by the membership, and

WHEREAS, unlike most other committees of the Society, the Committee on Names of Fishes is not adapted to function effectively on an annual basis with a rapid turnover of personnel, and

WHEREAS, by approval of the Society in 1951, this committee serves jointly toward the attainment of its objectives with a similar committee of the American Society of Ichthyologists and Herpetologists, and

WHEREAS, the best interests of this committee and the Society would be promoted by presidential appointment of the members in order (1) to give continuity of membership for at least the period of revision between editions of the *List of Names*; (2) to facilitate change of personnel if the need arises; and (3) to facilitate coordination between this Society and the Society of Ichthyologists and Herpetologists on the names of fishes; now, therefore,

BE IT RESOLVED, that the following change in Section 15 of the Bylaws be made: after the word "members" in line 9, delete "named by the nominating Committee and elected by the membership," and substitute, "appointed by the President."

Mr. Swartz made a motion for adoption, which was seconded by Reeve M. Bailey, put to a vote, and carried.

Resolution No. 5 — Encouragement of Biological Aspects of Oceanographic Research

WHEREAS, the American Fisheries Society has constantly encouraged biological research in marine and inland waters since 1870, and

WHEREAS, the National Academy of Science-National Research Council has recently published reports pointing out the nation's critical need for an expanded oceanographic research program, and

WHEREAS, the United States Senate and the House of Representatives have each created a special committee to study oceanographic problems and recommend new legislation and programs to implement the National Academy of Science-National Research Council reports, and

WHEREAS, a careful study of these reports and publications indicated that the biological aspects of the proposed program are subordinated to other disciplines; now, therefore,

BE IT RESOLVED, that the Society (1) commends the Administration and the Congress for the interest they have expressed in expanding the national effort in oceanographic research; (2) expresses its concern that the vitally important biological aspects of the oceanographic research program be given more adequate recognition in the development and implementation of plans, and

BE IT FURTHER RESOLVED, that copies of this resolution be sent to Dr. George Kistiakowsky, Chairman of the Federal Council for Science and Technology, to the President of the National Academy of Science-National Research Council, to the House Merchant Marine and Fisheries Sub-Committee on Oceanography, and to the Senate Interstate and Foreign Commerce Committee.

Motion for adoption was made by Mr. Swartz. It was seconded by Robert M. Paul and carried.

Resolution No. 6 — Access to Recreational Areas from Highways

WHEREAS, many limited access highway systems in the United States and Canada do not at present provide access to recreational areas, and

WHEREAS, a lack of consideration prevents optimum utilization of those areas, and

WHEREAS, more adequate utilization could be achieved by sympathetic consideration of access to recreational areas by Federal, Provincial, and State Highway Departments; now, therefore,

BE IT RESOLVED, that the American Fisheries Society does hereby recommend to the respective Highway Departments that every reasonable effort be made to provide for access to recreational areas in new and existing limited access highway systems.

Mr. Swartz moved adoption of the resolution. George Eicher seconded the motion which was put to a vote and carried.

Resolution No. 7 — Opposition to Construction of Nez Perce Dam in the Columbia River

WHEREAS, the Columbia River system, including the Snake River, supports the greatest runs of anadromous fish in the United States and as such is important to the people of the nation, and

WHEREAS, proposals have been made to construct a hydroelectric dam at the Nez Perce site on the Snake River, and

WHEREAS, construction of any dam on the Snake River would cause serious damage to these valuable runs of anadromous fishes, and

WHEREAS, the problem of passing migrant fish over and through these dams has not been solved, and

WHEREAS, a recent study of the U. S. Corps of Engineers recommended that in view of the fishery problems and the importance of the Salmon River as a fishery stream the construction of high dams on this river be postponed until fish passage problems are solved; now, therefore,

BE IT RESOLVED, that the American Fisheries Society, recognizing the demands being made for further power development on the middle Snake River stand unalterably opposed to the construction of the Nez Perce Dam which would block the Salmon River; now, therefore,

BE IT FURTHER RESOLVED, that the Society endorse the construction of the High Mountain Sheep Dam as a power project which would be least detrimental to the maintenance of this valuable fishery resource, and

BE IT FURTHER RESOLVED, that copies of this resolution be sent to the Governors of Oregon, Washington, and Idaho, the Secretary of the Army, the Secretary of the Interior, and the Federal Power Commission.

Mr. Swartz's motion for adoption was seconded by Percy Viosca. John Dequine interpreted the resolution as endorsing the construction of the High Mountain Sheep Dam and asked for clarification. Robert Meigs stated that any dam as large as those discussed will damage fish. He stated:

> However, the Nez Perce site is immediately below the mouth of the Salmon River. The High Mountain Sheep site is above that, and just below the mouth of the Amahaw River which is also a very important stream for steelhead and salmon. The proposal of the High Mountain Sheep would, of course, leave Salmon River free and unobstructed, and the proposal further calls for a diversion of the lower part of the Amahaw River so that it would be turned into the Snake River below the High Mountain Sheep, it will be leaving it unobstructed. Of the two, certainly the High Mountain Sheep proposal is preferable, inasmuch as we all recognize the Salmon River as being the backbone of the Snake and Columbia River system at present.

Mr. Dequine moved an amendment, that the word "endorse" with reference to the High Mountain Sheep Dam be changed to "do not seriously object to." The motion was seconded by Percy Viosca. Robert M. Paul spoke in favor of the amendment by Mr. Dequine. He pointed out:

> I think it is also fair to point out, I think there may be a little bit of some misunderstanding on the part of some members that the construction of the High Mountain Sheep Dam in itself does not automatically guarantee the preservation of the Salmon River as a fish sanctuary.
>
> I know that you are probably aware that there are already bills in Congress to allow the construction of low dams on the Salmon River, and this proposal, I think, deserves very careful study and thought by the Society before we go on record in favor of it. I think Mr. Dequine's amendment goes a long way to clarify the exact intention of the membership.

The amendment was put to a vote and carried. A hand vote was called for on the resolution. With 26 voting "yes" and 28 voting "no," the motion was lost. After the loss of the resolution, Raymond E. Johnson pointed out that the subject of high dams had been previously discussed but that a large portion of the membership were not fully aware of such construction. He suggested that the President appoint a committee to study the situation and make a recommendation to the Society for a position which should be maintained on this important question.

Resolution No. 8 — Transfer of State of Maryland to Southern Division

WHEREAS, members of the American Fisheries Society from the State of Maryland are now assigned to the Northeastern Division, and

WHEREAS, Maryland is a member of the Southeastern Association of Game and Fish Commissioners, and

WHEREAS, Maryland's fishery problems are more closely related to those of the states in the Southern Division, and

WHEREAS, a majority of the members from the State of Maryland have requested transfer; now, therefore,

BE IT RESOLVED, that the Society amend Section 21 of the Bylaws to remove Maryland from the roster of states in the Northeastern Division. and amend Section 22 of the Bylaws to add Maryland to the roster of states in the Southern Division.

Mr. Swartz's motion for adoption was seconded by I. B. Byrd and carried.

Resolution No. 9 — Pesticides Research

WHEREAS, the use of chemical insecticides. herbicides, and fungicides continues to grow in volume on public and private lands of the United States and Canada, and

WHEREAS, a host of new chemical pesticides is appearing on the market and their use by public agencies and private individuals is promoted and often initiated without adequate knowledge of the immediate and long-range effects upon forms of life other than the target organism; now. therefore,

BE IT RESOLVED, that the American Fisheries Society urge the federal, state, and provincial agencies to expand research programs to determine the effect of these chemicals on fishes and wildlife, and

BE IT FURTHER RESOLVED, that the American Fisheries Society urge the President to sign S. 1575 which amends the Pesticides Research Act of 1958 by increasing the authorization for appropriations sufficient to meet the need for determining the effect of these new chemicals on fish and wildlife, and

BE IT FURTHER RESOLVED, that copies of this resolution be sent to appropriate officials in Canada and the United States and to the appropriate Senate Committee.

Mr. Swartz's motion for adoption was seconded by George Rounsefell, put to a vote, and carried.

Resolution No. 10 — Thanks for Assistances and Hospitality

WHEREAS, the American Fisheries Society has been the guest of the State of Florida and has enjoyed the warm and friendly hospitality of the city of Clearwater; now, therefore,

BE IT RESOLVED, that our appreciation be extended to the Florida Game and Fresh Water Fish Commission and to the Convention Committee made up of many Florida state and city agencies and many Florida business concerns who have combined to make our convention so informative and enjoyable.

A motion was made for adoption by Mr. Swartz and approved by a rising vote.

In concluding his report Mr. Swartz pointed out that some very important resolutions had been considered, including the one from the Northeastern Division and Southern Division concerning the raising of dues to $15 and the employment of an Executive Secretary. The committee, while endorsing the objectives of these resolutions, did not feel that they should be presented until the information presented by the Finance Committee could be thoroughly evaluated and studied. George Eicher pointed out that in the postcard poll referred to in the report of the Finance Committee, analysis of 725 votes received from different areas indicated the same trend and suggested that the entire membership would have voted in a similar manner. Thirty-four percent of the vote on Executive Secretary were against the secretary, and 50 percent more were in favor of a secretary only after additional study. He endorsed the omission by the Resolutions Committee of the presentation of a resolution for Executive Secretary. He stated that the additional $5 suggested would not cover the estimated 25 to 30 thousand dollars required annually for an office of Executive Secretary.

Mr. Eicher moved that the President appoint an *ad hoc* committee to make a thorough study of the factors involved in the establishment of an Executive-Secretary position. This study is to include an analysis of the financial aspects, and the possibility of joint participation in an executive secretariat with some organization with similar composition, interests, and problems. This committee will complete its study and have its recommendations by the time of the Denver meeting in 1960. The motion was seconded by J. H. Cornell.

George Rounsefell asked whether or not there had been a definition of the duties of the proposed secretary and if it was contemplated that he would take over editorial, publishing, and many committee duties. John Dequine stated that he had prepared a speech on this subject, but that in view of the motion by Mr. Eicher that an answer should be deferred. Mr. Rounsefell further stated that he felt the employment of a full-time editor would be more desirable than the employment of a secretary, if employment of full-time personnel were contemplated. In response to a question by President Lawrence, Edward Schneberger stated:

> To date there has been no definition or designation of specs of the type of person that would serve as Executive Secretary, or a delineation of his duties. There have been many ideas, and I think that is one of the things that this committee should consider in studying this problem as to not only how to finance this man, but tell us what he would do, find out his duties and functions, and also at the same time consider any constitutional or bylaw changes that might be necessary in creating this new position. Undoubtedly it would be the elimination of some duties and taking over some burdens of others.
>
> There are two things that I think a lot of people do not realize that have worked with the Society. One is the present amount of work that the Secretary-Treasurer now carries on. He has a lot of correspondence, he has a lot of records to keep, and he also has a lot of funds to manage in one way or another.
>
> I don't think anybody at this time could give us a good definition of the specs of this man or this employee, and therefore I think it is a matter that the committee should be instructed to follow through on.

The motion was put up for vote and carried.

President Lawrence called for a report of the Nominating Committee. In the absence of

the chairman of the Nominating Committee, the following report was presented by Eugene Surber:

I will first read the slate as selected by the Nominating Committee:

President.....James W. Moffett, Michigan
First Vice-Pres.....Kenneth D. Carlander, Iowa
Sec. Vice-Pres.....Justin W. Leonard, Michigan
Richard S. Croker, California
Sec.-Treas.....E. A. Seaman, Virginia
Librarian.....Howard A. Tanner, Colorado

Committee on International Relations

William A. Dill, Italy, Chairman
Vernon Applegate, Michigan
F. E. J. Fry, Ontario
W. J. K. Harkness, Ontario
Y. Hiyama, Japan
Marcel Huet, Jr., Belgium
Milner B. Schaefer, California

Committee on National-State Relations

Edward Schneberger, Wisconsin, Chairman
C. R. Gutermuth, Washington, D. C.
Milton C. James, Oregon
Raymond E. Johnson, Washington, D. C.
Richard H. Stroud, Washington, D. C.

Committee on Hydrobiology and Fish Culture

Frank P. Hooper, Michigan, Chairman
I. B. Byrd, Alabama
Clarence P. Idyll, Florida
William F. Sigler, Utah
Lloyd L. Smith, Jr., Minnesota
Stanislas F. Snieszko, West Virginia
William C. Starrett, Illinois

Finance Committee

Seth Gordon, California, Chairman
George Eicher, Oregon
Lyle M. Thorpe, Connecticut

Committee on Commercial Fisheries

Seton H. Thompson, Florida, Chairman
Paul H. Eschmeyer, Michigan
Ralph Hile, Michigan
John L. Kask, Ontario
Alfred W. H. Needler, British Columbia
George A. Rounsefell, Texas
Hjalmar Swenson, Minnesota

The Resolutions Committee presented a resolution which gives the President the power to appoint the Committee on Names of Fishes and the Water Pollution Committee.

In selecting nominees we recognize the desirability of periodic representation from Canadian officials in American Fisheries Society officers. However, there must be acceptable and willing candidates. This year one possible candidate, William E. Ricker, declined. John Kask refused a committee chairmanship and would doubtless have done the same with officer nomination; hence there is no Canadian this year. The Committee tried to get the broadest geographical representation and to get younger men who have not had too much opportunity to serve the Society. It selected Richard Croker, a commercial fisheries official, in recognition of west coast and commercial fishing industry. He was unable to attend this meeting due to factors beyond his control.

Mr. Surber moved that the members of the International Relations Committee, the National-State Relations Committee, the Committee on Hydrobiology and Fish Culture, the Finance Committee, and the Commercial Fisheries Committee be elected. After calling for other nominations to the standing committees, President Lawrence closed the nominations. John B. Moyle seconded the motion for approval of the slate presented. The proposed slate of standing committee members was unanimously approved.

Mr. Surber moved that James W. Moffett be elected President. Reeve M. Bailey moved to close the nominations. The motion to close the nominations was seconded by Ralph Hile. James W. Moffett was elected President by unanimous vote.

Mr. Surber moved that Kenneth D. Carlander be elected First Vice-President. The motion to close the nominations was made by J. H. Cornell and seconded by Lee S. Roach. Kenneth Carlander was unanimously elected.

Mr. Surber moved that Justin W. Leonard and Richard S. Croker be nominated for Second Vice-President, and requested that John Moyle, Croswell Henderson, Clarence Tarzwell, and Harry Dupree act as tellers. The motion was made to close the nominations by Reeve Bailey and seconded by Clarence Tarzwell. The paper vote for the office of Second Vice-President resulted in 42 for Justin Leonard and 50 for Richard Croker. President Lawrence declared Richard S. Croker elected Second Vice-President.

Mr. Surber moved that E. A. Seaman be reelected Secretary-Treasurer. The motion was made and seconded from the floor that the nominations be closed. Mr. Seaman was elected Secretary-Treasurer by a voice vote with no dissenting votes.

Mr. Surber moved to elect Howard A. Tanner librarian. The motion was made and seconded from the floor to close the nominations. Dr. Tanner was elected Librarian by unanimous voice vote.

The newly elected president, James Moffett, was escorted to the rostrum where retiring President Lawrence turned over the gavel. George Eicher moved that retiring President Lawrence be commended for his work with the Society during the past year. The motion was seconded by Clarence Tarzwell and passed by a rising vote. President-elect Moffett named the following appointive committees. [ED. NOTE: Appointments were made subsequent to the close of the business session.]

Committee on Names of Fishes

Reeve M. Bailey, Michigan, Chairman
Ernest A. Lachner, Washington, D. C.
C. C. Lindsey, British Columbia
C. Richard Robins, Florida
Phil M. Roedel, California
William B. Scott, Ontario
Loren P. Woods, Illinois

Committee on Water Pollution

Clarence M. Tarzwell, Ohio, Chairman
Marvin O. Allum, South Dakota
T. W. Beak, Ontario
G. E. Burdick, New York
James T. Davis, Louisiana
J. C. Fraser, California
Terrence P. Frost, New Hampshire
Forrest R. Hauck, Idaho
William H. Irwin, Oklahoma
Eugene W. Surber, Georgia
William M. Van Horn, Wisconsin

Editorial Board

Lloyd L. Smith, Jr., Minnesota, Editor
J. R. Brett, British Columbia
Robert S. Campbell, Missouri
Allan DeLacy, Washington
W. Harry Everhart, Maine
F. E. J. Fry, Ontario
Shelby D. Gerking, Indiana
Croswell Henderson, Ohio
John B. Moyle, Minnesota
George A. Rounsefell, Texas
Stanford H. Smith, Michigan

Membership Committee

Kenneth D. Carlander, Iowa, Chairman
Norman Benson, Utah
Richard Croker, California, Vice-Chairman
Allan DeLacy, Washington
James Galligan, Connecticut
Gordon Hall, Florida
Robert Jenkins, Washington, D. C.
Nigel Martin, Ontario
J. T. Shields, South Dakota
Al Swartz, Massachusetts
William Zarback, Ohio

Program Committee

W. R. Seaman, Colorado, Chairman
Alex Calhoun, California
Glenn Gentry, Tennessee
Jack E. Hemphill, New Mexico
Peter Larkin, British Columbia
Cliff Millenbach, Washington
John B. Moyle, Minnesota

Committee to Explore Joint Meeting with the International or other Organizations

E. A. Seaman, Virginia, Chairman
William Harkness, Ontario
Mason Lawrence, New York

Professional Standards Committee

Lloyd L. Smith, Jr., Minnesota, Chairman
Charles C. Bowers, Kentucky
Louis R. Garlock, New Mexico
Shelby Gerking, Indiana
David Haskell, New York
Nigel V. Martin, Ontario
Ralph P. Silliman, Washington, D. C.
Richard Van Cleve, Washington

President-elect Moffett announced that Lloyd L. Smith, Jr. had agreed to accept the position of editor replacing John B. Moyle, who tendered his resignation.

There was some discussion concerning the failure of the resolution on the Nez Perce Dam and its effect on a resolution passed in 1957 condemning this construction. Seth Gordon stated that under the rules of the Society the previous resolution would stand since there had been no resolution accepted which would nullify the previous action.

Clarence Tarzwell moved that John B. Moyle be given a vote of thanks for his efforts in behalf of the new quarterly and as Editor of the Society for the past 3 years. The motion was approved by a rising vote.

I. B. Byrd moved that thanks be given Secretary-Treasurer Seaman for the services he has performed for the Society. The motion was approved by a rising vote.

After concluding announcements President-elect Moffett declared the business sessions adjourned at 4:15 p.m.

Report of Secretary-Treasurer

E. A. Seaman

The Society's books were audited this year by Mr. Howard C. Haire, Public Accountant, Washington, D. C. His report and a financial statement have been placed in the hands of the Audit Committee. These will appear as a part of this report in the quarterly *Transactions*.

Our cash balance as of July 1, 1958, was $6,118.76. Receipts for the fiscal year 1958-59, consisting of annual dues, dividends, and sale of publications, totaled $24,819.78, $4,147.00 of which was from cashing U. S. Government Bonds, as approved and transacted in the previous fiscal year. Increase of membership dues accounts for the marked increase in receipts this year over the past. Disbursements totaled $20,581.19, the greater part of which involved printing costs. As of June 30, 1959, the cash balance was $10,360.42.

The total assets of the Society as of June 30, 1959, were $21,692.57. This included cash on hand, U. S. Government bonds (value of June 30, 1958), corporate stock, and fixed assets in the form of office equipment of $903.18.

Following the normal fiscal year billing of membership dues, the Society as of August 31, 1959, had a cash balance of $16,258.15.

For further details on the financial status of the Society full accounting herewith follows:

FINANCIAL REPORT
FOR THE FISCAL YEAR JULY 1, 1958 TO JUNE 30, 1959

Cash Balance as of July 1, 1958		$ 6,118.76
Receipts:		
Membership Dues:		
a. Active	$14,394.87	
b. Official	1,880.00	
c. Library	1,131.45	
d. Sustaining	460.00	
e. Life	345.00	
Other:		
Sale of Transactions and Special Publications	2,362.65	
Dividends, Stock	98.81	
Proceeds from U.S. Government Bonds	4,147.00	
Total Receipts		24,819.78
Total		$30,938.54
Disbursements:		
Printing Expense	$12,661.47	
Postage and Office Supplies	875.85	
Meeting Expense	206.00	
Reporting Service	310.57	
Audit Service	100.00	
Fidelity Bond	62.50	
Insurance	95.01	
Safe Deposit Box Rental	5.50	
Editorial Service	1,986.51	
Miscellaneous	16.40	
Advertising	225.00	
Secretary's Stipend	249.99	
Officer's Travel Expense	229.58	
Stenographical and Secretarial Service	2,545.25	
Dues	302.00	
Purchase of Kardex Cabinets (Asset)	683.31	
Telephone	26.25	
Total Disbursements		$20,581.19
Balance		$10,357.35
Petty Cash Credit Balance		3.07
Cash Balance as of June 30, 1959		$10,360.42

FINANCIAL REPORT
JULY 1, 1959 THROUGH AUGUST 31, 1959

Cash Balance as of July 1, 1959		$10,360.42
Receipts:		
Membership Dues:		
a. Active	$ 5,599.10	
b. Student	330.00	
c. Foreign	42.00	
d. Military	10.00	
e. Official	520.00	
f. Library	310.00	
g. Sustaining	310.00	
h. Life	75.00	
Other:		
Sale of Transactions and Special Publications	268.75	
"Fisheries as a Profession" brochure	11.00	
Dividends, stock	19.20	
Total Receipts		7,495.05
Total		$17,855.47
Disbursements:		
Printing Expense	$ 428.87	
Postage	12.55	
Office Supplies	30.35	
Petty Cash	175.00	
Stenographical Services	449.25	
Secretary's Expense	9.64	
Secretary's Stipend	166.66	
Editor's Expense	25.00	
Annual meeting expense Clearwater	200.00	
Contribution 6th National Watershed Congress	100.00	
Total Disbursements		1,597.32
Cash Balance as of August 31, 1959		$16,258.15

The Secretary has prepared and mailed out to the membership six Newsletters and conducted one membership poll on the subject of increasing dues. A brochure, *Fisheries as a Profession*, prepared by the Editor and Secretary was published and has been well received

by the educational field. The original stock of 10,000 copies is about exhausted. A new membership-application brochure was printed since the last annual meeting. With the advent of publishing the new quarterly *Transactions* two ads concerning it were placed in the *Bulletin* of the American Institute of Biological Sciences and in *Science*.

The Secretary-Treasurer represented the Society at the annual board meeting of the American Institute of Biological Sciences, Pennsylvania State University, on August 29, 1959. The Secretary-Treasurer also represented the Society at several steering committee meetings in Washington, D. C. of the National Watershed Congress, of which the Society is a participating organization.

Business of the Society has increased greatly. Correspondence has more than doubled. There is evidence of far more extensive concern about the Society, and the membership has expressed interest in receiving Newsletters frequently.

Report of Librarian

HOWARD A. TANNER

This report covers the period from September 1, 1958, through August 31, 1959. Since my last report the Society has shifted to the new quarterly publications. The business and mailing associated with four issues a year is going to complicate considerably the operations of the Librarian's office. Many times greater numbers of parcels must be mailed and the accompanying correspondence has been increased appreciably. I merely wish to comment that the shift to a quarterly basis, as anticipated, has caused no end of increased activities in your Librarian's office; increased correspondence and increased number of parcels have complicated procedures considerably.

During this period the following sales and distribution of volumes occurred:

110	volumes were sent out of the Librarian's office on request of the Secretary-Treasurer; the monies for these volumes have been paid to the Secretary-Treasurer		
30	copies of Special Publication No. 1	@ $0.25 each	$ 7.50
32	paper-bound indexes	@ 1.00 each	32.00
5	cloth-bound indexes	@ 1.50 each	7.50
110	copies of volumes 76, 77, 78, 79, 80	@ 2.00 each	220.00
107	copies of volumes 81, 82, 83, 84, 85, 86	@ 5.00 each	537.00
135	copies of volume 87	@ 5.00 each	675.00
124	copies of volume 88	@ 2.50 each	310.00
19	copies of miscellaneous numbered volumes	@ 1.00 each	19.00
		Total	$1,808.00
	Postage received		1.25
	Returned volumes		5.50
		Grand total	$1,815.75

The total amount of $1,815.75 has been forwarded to the Secretary-Treasurer and in addition there are accounts outstanding totaling $463.00. The overrun of number 2, volume 88, has not yet been received by the Librarian's office but is anticipated daily.

The sale of volumes 76 through 80 available at a bargain rate has declined considerably and accounts for the slight decline in total sales.

As I have reported in past years, all volumes preceding volume 76 with very few exceptions are out of print and unavailable. Recent correspondence with the J. S. Canner Company, Boston, Massachusetts, indicates that they will very soon complete the microcarding of all out-of-print volumes.

No particular problems exist in the Librarian's office. Storage for volumes continues to be supplied by Colorado State University and is adequate and safe.

Report of Committee on Professional Standards for Fishery Biologists

LLOYD L. SMITH, JR.

INTRODUCTION

At some point in the development of all professions the need for standards of individual competence and performance becomes evident. This need arises from public demand for protection against poorly trained or unethical operators and from the desire of capable members of the profession to preserve and improve their own status as responsible practitioners of some skill. Medicine, law, engineering, and many professions rendering service to the public have long maintained standards through professional so-

cieties and public licensing systems. As soon as a profession progresses from its exploratory and developmental stages into a recognized activity requiring special training and forming an integral part of the social and political organization of the community, it must meet certain standards or cease to grow.

In the opinion of many members of the American Fisheries Society, fishery biology as a profession has developed beyond the empirical findings of the practical fish culturist and skilled investigations of the strictly academic or research institutions. It occupies a position of public trust where it must be carried on by highly trained workers who are essentially responsible to the community regardless of the exact nature or objective of the research or management project. At numerous informal meetings in the past few years this problem has been discussed and many tentative solutions suggested. An institute of research biologists has been formed to recognize and promote high standards of excellence in fishery research. In recognition of the importance of the problems an *ad hoc* committee was appointed by the president of the American Fisheries Society at its 88th meeting to explore the need for professional standards in fishery biology and make such recommendations as were found to be appropriate.

The function of the committee, therefore, has been limited to an exploration of the problems of setting professional standards for fishery biologists and the making of such recommendations as appear to be justified by existing facts and opinions of recognized fishery biologists of high professional status. Although the committee was not concerned with any problems related to qualification for membership in the Society, the implications of recognizing biologist and non-biologist groups within the Society should be thoroughly explored. Whether or not the Society is eventually to become a strictly professional group of biologists or is to retain its present broad base of membership is an extremely important question which will be closely bound with the future effectiveness of the organization, but professional standards for biologists are a concern of the Society at present only as they affect the welfare of one group of its members and the sponsorship of more sound resource management. The committee therefore has not related any of its findings or recommendations to problems of membership in the American Fisheries Society.

The factors which have led to a demand for professional standards may be outlined under several headings.

Deficiency in qualifications of fishery biologists. — At the present time there are many persons employed or seeking employment as fishery biologists in some public agencies who are unqualified or only partially qualified to work in this field. This condition may result from personnel policies, an insufficient pool of properly trained people, or lack of clear understanding of needs.

Inadequate description of a fishery biologist. — There appear to be no clear cut and generally accepted criteria which describe the function and qualification of professional workers in fishery science and fishery management. It is, therefore, difficult to establish professional status in some organizations or to gain public acceptance as trained professionals. In large and well established fishery organizations which are engaged in research or management, standards consistent with the need for professional handling of problems have been developed. In smaller or younger organizations or in those where there is political instability, standards have often been flexible or non-existent.

Consequences of deficiencies in professional status. — In consequence of the deficiencies outlined above, salary levels are frequently inconsistent with the amount of training and experience required to carry on adequately the duties of a biologist or fishery scientist and biological opinion is not highly regarded. The recent failure of federal agencies to upgrade biologists when chemists, physicists, and other technical personnel were raised in salary status is an illustration of this problem. In some organizations well trained professionals have been released and replaced by poorly qualified people or used on jobs which did not utilize their professional talents.

Small pool of well trained men. — There are an inadequate number of well qualified men entering training programs in the fisheries field in comparison to those entering other professions such as chemistry, physics, and engineering. This lack is due in part to better professional status in other fields and better remuneration resulting from recognition of the professional nature of the work. Unavailability of properly trained men results in the filling of many positions in various agencies with persons not well qualified for the job.

Poor public understanding of professional needs and qualifications. — There is a general misunderstanding on the part of the public concerning the professional qualifications of biologists and the highly technical demands of the work. Some administrators without technical background or extensive professional experience share this lack of appreciation of the professional biologist.

Are formalized standards the answer to the problem?—It has been assumed by those who promote the adoption of professional standards that most of the problems enumerated above will be solved by establishment of an adequate set of criteria for judging professional qualification. It is pointed out that: (1) hiring agencies will have definite minimum standards by which to judge candidates for professional work; (2) political manipulation of personnel will be minimized; (3) wasting of talent on non-technical jobs will be minimized; (4) educational institutions can do a better job of providing adequately trained men; (5) salary levels can be made consistent with those in other fields requiring similar training and experience; and (6) advantages of professional prestige will raise the quality of biological personnel and recruit more well qualified people to the field.

Among those who question the desirability of establishing professional standards now, the following opinions have been voiced: (1) the state of the science is not enough advanced to permit the setting of standards without hampering its future free development; (2) advancement in the field will result from improvement in basic training and the increased number of highly trained and dedicated men working in fishery biology; (3) since fishery biology is essentially in a state requiring the best scientific thought available to establish a larger body of principles on which management can be based, any standards set at the present time will soon be obsolete; (4) setting of standards will tend to formalize training programs and restrict the educational breadth of trainees; and (5) well qualified personnel in most research agencies and in agencies committed to action programs do not suffer from lack of recognition. Workers personally affected by lack of professional recognition frequently are those whose qualifications may be inadequate for their desired professional status.

QUESTIONS THE COMMITTEE EXPLORED

In view of the problems outlined above the committee has attempted to explore the following questions: (1) what is a fishery biologist and what are his functions; (2) is there a need for classification of biologists into management and research groups; (3) what is necessary training and experience for qualified fishery biologists; (4) is it desirable to accredit institutions for training of fishery biologists; (5) is it practical and desirable for the Society to establish an accreditation service for members who are biologists; and (6) should a code of professional ethics for biologists be established at this time.

DEFINITION OF FISHERY BIOLOGIST

One of the most serious problems to be solved and one which should be thoroughly discussed by the membership of the Society is the exact nature and scope of the professional fishery worker's duties and talents and the nature of his formal training. The question can be broken down more specifically as follows: (a) must all professional fishery workers have formal biological training; (b) is training in ancillary fields such as mathematics, physics, chemistry, botany, bacteriology, etc., plus experience in fishery research, adequate qualification for fishery-biologist status; (c) can workers without formal training in the sciences be qualified as fishery biologists by experience alone; and (d) should the term "biologist" be changed to "scientist."

It has been pointed out by a number of people that the fishery field is expanding rapidly in the areas of physics, chemistry, mathematics, and other sciences and that future progress will be very dependent on the efforts of workers with special talents in these disciplines. The fact remains, however, that the fishery biologist is presumed to be an expert in biological dynamics. He must therefore have fundamental competence in biology in order to integrate the findings of the other fields to bring about a solution of a fishery problem. The specialist in other fields may acquire biological competence by association with biological problems or by additional formal training, but until he has demonstrated such competence it would appear that he is better designated as a statistician, chemist, botanist, bacteriologist, etc. It is recognized that administrative procedure, merit-system ratings, and operational problems in various

conservation agencies make it convenient to lump all people working with fisheries problems into a category of "fishery biologist." Significant development of professional standards and definition of areas of competence cannot be influenced by administrative expediency. The committee does not minimize the importance of the specialists outside fishery biology, especially the mathematician, physicist, chemist, and botanist. It believes, however, that the setting of standards for professional fishery workers would require that all those designated as fishery biologists must have formal training or have demonstrated competence in fishery or aquatic biology. The suggestion that the term *biologist* be dropped in favor of *scientist* has merit. *Scientist*, however, implies a purely research function and would require either the broadening of qualifications to a point where they could be meaningless or would require demonstration of biological competence. In the latter case there would be little value in changing the name from fishery biologist.

Although there was not complete agreement among committee members, the majority suggests that for the purpose of considering standards for professional fishery workers, the designation *fishery biologist* be used and described as follows:

a. A fishery biologist is a professionally trained person capable of defining and investigating problems related to fisheries, and of proposing scientifically sound solutions of the biological problems in sport and commercial fisheries.

b. The fishery biologist can be expected to have a working knowledge of basic biology, chemistry, physics, and mathematics as applied to aquatic problems and a specialized knowledge of aquatic biology and fisheries. He must also be capable of presenting results and recommendations in suitable written and oral form.

CLASSIFICATION OF FISHERY BIOLOGIST ACCORDING TO FUNCTION

It is generally recognized that in administrative agencies there are two broad categories of function exercised by a fishery biologist. One is the strict field of research which is concerned with the investigation of problems for the purpose of formulating new principles and discovering new relationships. The other is concerned primarily with inventory of biological conditions and the application of principles determined by research to the conduct of action programs designed for resource management. Workers engaged in either of these activities may switch from one to the other if their capabilities are sufficiently broad. Individuals are usually ideally suited by temperament and inclination to one activity or the other and the demands of the two activities require talents which are somewhat independent. The management biologist should ideally have a talent for public relations, sound administrative judgment and business sense, and a liking for participation in action programs. The research biologist, on the other hand, needs an ability to carry on sustained analytical work, training and talent for theoretical analysis, and familiarity with a wider range of ancillary subjects than is required of the strictly management man. The research biologist is likely to have less interest in public relations and in the management details of action programs. The qualifications and temperament of the men ideally suited for these jobs and the functions themselves are certainly not mutually exclusive. In most organizations, however, there is a more or less clear demarcation, functionally, between the two activities even though all professional workers may be termed *biologists*.

In many administrative agencies there is a rather serious problem of classification because of the multiplicity of activities in the entire conservation operation and because functionally, and on the basis of qualifications required by these agencies, distinction between related activities is not clearly defined. In consequence, there is often no differentiation between different types of fishery workers with biological requirements except in the matter of rank. The conditions described above have led to the suggestion that two types of biologists, *management* and *research*, be designated and that separate qualifications for each be enumerated. Those favoring such a separation point out the differences in personality, training, and capabilities which are inherent in the requirements of the two activities. They feel that such a separation is necessary to insure the most efficient production of workers in the two types of work.

A number of competent biologists and administrators do not favor such a separation. They summarize the reasons for maintaining one class of fishery biologists in the following manner. Men frequently change from one type of activity to the other and the line between research and management is hard to draw in

many cases, especially where the solution of a management problem depends upon new research findings; the difference in qualification for the two activities is dependent on training and/or experience in addition to the minimum amount of formal training which should be required of all biologists. By setting up two classes of biologists a real or imagined problem of first- and second-class biologists may arise in administrative groups. Such a connotation would, in some measure, defeat the whole purpose of setting up professional requirements. Conservation workers whose essential duties are to conduct action programs, but do not include strictly administrative functions, require the same basic training as research workers if they are to be truly effective.

Although there are obvious advantages to the dual system of classification insofar as training and preparation is concerned, the committee believes that the task of setting two groups of standards would be difficult and perhaps impossible to accomplish at this time. For the purpose of setting of minimum standards, therefore, it is believed that one classification of biologists should be recognized until the areas of functional activity are more thoroughly defined in the administrative agencies. Those people with biological and management duties who may not have the necessary training or background to qualify as fishery biologists could be given other designations for administrative purposes. If the administrator wishes to assign a qualified biologist to duties not requiring his full talent or demanding talents which he has not developed, the problem must be considered an administrative one.

The fishery *research* biologist can be so designated, if necessary, and appropriate additional requirements of training, experience, and demonstrated ability be demanded. Recognition and standards for such research men could be made by the American Institute for Fishery Research Biologists.

REQUIREMENTS FOR CLASSIFICATION AS FISHERY BIOLOGISTS

At the outset of a discussion of standards of accreditation and desirable formal training programs for biologists, three things must be clearly understood. First, any significant and meaningful standards will exclude some individuals who are now nominally considered to be fishery biologists or who may feel that their background training should qualify them for a fishery-biologist rating. Such exclusion will necessarily be unsatisfactory to the individuals concerned and possibly to their administrative organizations or the schools in which they were trained. It is a necessary result of setting standards if the problems which now appear to exist are in fact real. It would appear to be better not to attempt to set standards than to lower them to a point which would include all those who might like to be included as fishery biologists by virtue of their present positions. A second consideration is that qualifying standards will necessarily be dependent upon the definition of the fishery biologist and his function. Finally, any set of standards to have practical utility must be widely accepted and supported by the capable biologist in the field.

In the following discussion it has been assumed that the description of the fishery biologist outlined above would be the basis for the setting of standards but the committee did not feel that it could make definite recommendations until there was opportunity for further discussion by the membership of the points already raised. It was generally agreed by biologists that certain minimum standards of training must be met before a man can be considered competent to attack fishery problems. This training should include a comprehensive undergraduate college program in basic physical, mathematical, and biological sciences with either a major or minor in aquatic science, and a period of field experience or graduate training stressing research and management. For advanced research work a minimum of 2 to 3 years postgraduate training was held highly desirable and in most cases essential for effective research. The need for competence in communication and some breadth of background in humanities and other non-technical fields including foreign languages was also considered to be a definite asset for success in the biological field. Fishery courses, as such at the undergraduate level, were believed to be less important as background than basic science and mathematics. Courses specifically designed to teach techniques of management were generally held to be unnecessary in fundamental training.

Opinions on the extent and exact nature of formal training in terms of course work and in-service experience are extremely varied and probably reflect to some extent the familiarity

of different people with specific course offerings known to them. The curriculum outlined below is a broad concensus of practicing biologists on minimum undergraduate requirements for formal training leading to competence as a fishery biologist. For various specializations additional formal or in-service training would be required, and for research actual solution of problems under guidance will be a necessary part of preparation. The following outline is offered for discussion rather than for acceptance as a standard. It includes 80-100 semester hours (1½ quarter hours per semester) or approximately 60 to 80 percent of a normal 4-year course leading to a B.S. degree in recognized institutions offering technical work.

a. Communications (writing, speech, etc.); 15 semester hours.

b. Mathematics and statistics; 20 semester hours.

c. Biological science; 30-40 semester hours including a minimum of 15-20 semester hours in aquatic science (limnology, ichthyology, fishery biology, aquatic botany, aquatic fauna, oceanography, etc.).

d. Physical science; 15-20 semester hours (chemistry, physics, geology, meteorology, etc.).

Since many areas of specialization outside of biology are needed in fisheries work, it has been suggested that a degree from a reputable institution in mathematics, chemistry, physics, botany, or other biological science be accepted as minimum training for a fishery biologist provided that he has a minor in aquatic biology or has demonstrated by 2 or 3 years of experience with fishery problems, the production of scientific papers or reports on fishery problems, and the recommendation of competent colleagues in the field of fishery biology, that capability in biology has been acquired. It is believed that regardless of his competence in particular specializations a technician should not be considered a professional fishery biologist until he can apply biological thinking and knowledge to a fishery problem.

There are a few workers in the field who have not had formal training in the sciences which would qualify them for a rating of fishery biologist but who, by virtue of self training, experience with research problems in fishery biology, the production of scientific papers, and the recognition of their colleagues indicate that they can conduct the work of fishery biology in a satisfactory and competent manner. Such persons would have to seek accreditation as biologists on an individual basis and be accepted on the strength of the credentials presented. Any provisions in a set of professional standards to accommodate self-trained men would of necessity have to require an acceptable demonstration of competence in lieu of formal training or the remainder of the standards would be meaningless. Since there is a large group of management personnel which has been trained in the field and which does some types of biological work, a very careful consideration of this problem must be made.

ACCREDITATION OF TEACHING INSTITUTIONS

The accreditation of teaching institutions for the training of fisheries biologists may eventually be desirable. It involves many academic and philosophical considerations, however, in addition to the more obvious operational difficulties. For the present it appears to be impractical and should wait upon further development of the problems discussed above. Until such time as general standards of competence have been recognized and widely accepted in a particlar field, academic institutions will quite properly be reluctant to change curricula and course offerings to prepare students for specialization. Accreditation machinery is hard and costly to set up and presupposes a powerful organization of professionals to operate and back it. Only after the acceptance of standards by the Society, interested agencies, and institutions, can effective accreditation be considered.

ACCREDITATION SERVICE FOR MEMBERS

If standards are set up by the Society for fishery biologists, an accreditation service for members will be very desirable and necessary. Such a service, however, will require the full time availability of an executive secretary plus substantial help from a competent board of members. At the outset regional groups might be required to process the applications of present working biologists in order to set up a roster in a reasonable length of time. The establishment of this service is, therefore, dependent on acceptance of standards and the provision of adequate machinery within the Society.

CODE OF PROFESSIONAL ETHICS

A code of ethics is desirable in any profession, but if it is to be more than an affirmation of faith, it must be backed by adequate machinery for judgment and administration. First, acceptable professional standards must be set up, next a code of professional conduct consistent with these standards must be formulated, and finally a mechanism for judgment and discipline backed by a powerful organization must be created. In the opinion of the committee such a set of conditions, however desirable, cannot be met in the immediate future.

SUMMARY AND RECOMMENDATIONS

It is evident from the general interest and a canvas of many competent biologists that a clarification of the status of the professional worker in fisheries is desired by a large segment of the membership of the American Fisheries Society. Investigation of the problems of setting professional standards has shown that there is a wide divergence of opinion on the needs and possible solutions. The lack of a clear agreement on exactly what a fishery biologist is or should be and the exact objectives of the drive toward establishment of professional standards has been a major hindrance to a significant progress.

In essence the problem is to define a fishery biologist or scientist and to determine how he can be recognized. The mechanics of formal recognition or "professional standards" cannot be worked out until there is a more general agreement on the desirable status and background of the persons doing biological work and research. When this agreement is reached, the setting up of adequate criteria for professional designation can be attempted. The accomplishment of this task within the American Fisheries Society has important implications for the Society as well as for the individual members, although qualification for membership in the Society is not of immediate concern.

In view of the size and extent of the problems the committee has felt that its efforts should be limited to an exploration of the subject and the making of definite recommendations or suggestions only in the areas where general agreement could be reached. The committee therefore makes the following recommendations:

1. Since there is an obvious need for clarification of the professional status of workers in fishery management and research, efforts to establish adequate criteria for recognition of professional biologists or fishery scientists should be continued.
2. The suggestions for definition of fishery biologists offered in this report should be carefully considered as a basis for the further study of standards.
3. Accreditation of fishery biologists by the Society should be made only after standards have been formulated and generally accepted by working biologists.
4. Accreditation of academic institutions for teaching fishery biologists should not be attempted now.
5. An attempt to formulate a code of ethics for fishery biologists should not be made at this time.
6. The committee on professional standards for fishery biologists should be authorized to continue its work during the coming year with special emphasis on obtaining opinions and descriptions of duties from a broad sample of working biologists in both research and management areas.

Report of Joint Committee with The U. S. Trout Farmers' Association

H. S. Swingle

This Committee was appointed to consider problems of mutual importance to both organizations. A questionnaire was prepared and sent out to all the states, the provinces of Canada, and the U. S. Fish and Wildlife Service. Answers were received from all states except North Carolina, Georgia, Kansas, New Jersey, and Vermont. From Canada replies were received only from Manitoba, New Brunswick, Ontario, and Yukon. The information obtained from the answers received will be briefly summarized.

No trout are stocked in Alabama, Florida, Louisiana, Mississippi, Oklahoma, Texas, or Yukon. The Canadian provinces reported stocking annually 5,952,000 trout of all species and sizes; brook and lake trout were the principal species. In the United States a total of 183,059,845 trout were stocked annually, approximately half of which were rainbow trout (Table 1).

TABLE 1.—*Trout reported stocked in the United States and Canada by states, provinces, and federal agencies*

Species	Number stocked	
	United States	Canada
Rainbow	90,052,164	500,000
Brook	20,725,452	3,149,500
Kokanee	19,028,317	—
Cutthroat	11,125,621	—
Brown	10,698,770	206,000
Steelhead	2,858,389	—
Lake	2,112,076	1,695,000
Kamloops	1,310,521	162,000
Golden	65,688	—
Splake	29,620	240,000
Miscellaneous mixed[1]	25,053,227	—
Total	183,059,845	5,952,500

[1]Species were not reported separately.

Insufficient information was submitted to estimate the number of harvestable-sized trout (6 inches or larger) that were stocked annually in Canada; in the United States, various states and federal agencies stocked annually approximately 20 million harvestable trout weighing an estimated 4.8 million pounds. Of this total only 270,143 trout (7 to 14 inches and weighing 111,121 pounds) were reported purchased by five states from private trout farmers and none by the provinces. Only one state planned to increase their purchase of large trout from trout farmers.

The reported cost per pound for all sizes of trout produced by these agencies varied from 20 cents to $1.80, with an average of 89 cents. Cost of transportation and stocking was estimated by only two states at an average of 41 cents per pound of trout.

Commercial trout farmers sold to 25 states and 2 provinces 146,381,000 trout eggs; over 125 million of the total were eggs of rainbow trout. These were purchased from private producers in 13 states, 5 Canadian provinces, and 4 European countries. The European countries of England, Scotland, Denmark, and Sweden sold in the United States less than one million of these eggs.

Of the 25 states buying trout eggs, only eight had the eggs inspected, but most agencies treated eggs with various disinfectants upon arrival.

Many commercial trout farmers market part of their large trout by selling them to tourists and local fishermen through the operation of fishing pools or raceways, where the fisherman pays by the fish or by the pound for whatever he catches. Thirteen states require a state fishing license to fish such pools, while 26 states do not. Trout farmers feel that the requirement of a license to fish under such conditions is unfair and prevents sale of fish (or fishing) to many passing tourists. The price of a trip, or season fishing license, would appear a rather high tax upon a tourist for the privilege of catching a few trout produced by private business in private waters.

Most states and provinces furnish advice upon request of individual trout farmers. This was principally relating to the control of parasites or diseases. Also, the management techniques of the trout farmers were largely developed by research in state, provincial, or federal hatcheries.

All states and provinces allowed the sale of dressed trout, except Delaware. Vermont allowed the sale only of frozen dressed trout. Virginia allowed the sale of "imported" trout only. Six states required purchasers to have a bill of sale for dressed trout in possession. Four states required all dressed trout to bear a tag, attached by the state in which the retail sale was made. Trout farmers feel that such tags often mislead the customer into believing the trout were produced in that state, which is often not the case. Some even may have been produced in foreign countries. They would like some system of tagging developed that would indicate the producer and point of origin for advertising purposes, and to encourage the production of trout of high quality.

Relationships between state or provincial departments and commercial producers were found to be exceptionally good. Thirty-three states reported no points of conflict, while five reported minor points, several of which have been discussed. Other sources of friction mentioned were stocking of diseased fish in waters where the disease was previously unknown, planting fish without a permit, restricting fishing in private waters immediately below a trout farm, and the reduction of trout waters by the commercial use of big springs. The latter complaint would hardly be justified as springs are classed usually as private property.

Nineteen states and provinces have laws or regulations which must be complied with before private individuals can stock fish in public waters. This usually involves obtaining a permit for stocking from the appropriate fisheries department. Of the states having no regulations, two reported that commercial trout

farmers ask them for advice before selling fish for stocking.

The Joint Committee recommends careful consideration by both trout farmers and officials of state and provincial agencies of the surprisingly few causes of friction in order to eliminate them insofar as possible and to improve the cooperation between the two groups.

Report of Editorial Board

John B. Moyle

As you are all aware, the Society decided by a vote of its membership last year to change publication of the *Transactions* from an annual volume to a quarterly. Shortly after the 88th annual meeting, President Lawrence appointed a Format Committee to decide the shape that the new quarterly was to take. As a result of the activities of the Format Committee and those of the Editorial Board, a decision on the format of the present quarterly was reached about February 15. Material on hand was then edited to fit the new format and sent to the printer. The first number, that for January, appeared in July and the second, that for April, in August. The third number, that for July, is in final stages of printing and will be in your hands within a few days. This third number contains the proceedings of the 88th Annual Meeting together with papers. The fourth and concluding number of Volume 88, the October issue, is in galley and page proof and will be forthcoming before the end of the year.

Continuous publication of a quarterly requires a backlog of papers so that the Editorial Board can be working at least two issues ahead on the editing. For this reason the size of each issue of the quarterly this year has been restricted to about 75 pages. As a result we now have on hand material for the first number of Volume 89 that is approved for publication, edited, and most of which is at the printer for setting in type. In addition there is a good start on Number 2 of Volume 89 in the form of papers being considered by Associate Editors. This material together with that presented at the present meeting should assure the continuance of the quarterly with more editorial leeway and less strain than has been necessary this past year. Number 4 will contain an index for the entire Volume 88.

A few statistics might be in order here. By using a two-column format and a somewhat larger page the amount of material per page is about 50 percent more than in the previous annual volume. Some additional room for type is also gained by the better spacing of figures and tables made possible with the two-column format. The two preceding annual volumes, Volumes 86 and 87, each contained 37 papers of all lengths plus the Business Session and other material. Volume 88 when completed in the four quarterly numbers will contain about 50 longer papers, 25 short papers, notes and reviews, and the business session. Printing costs will probably be between $9,000 and $10,000 for Volume 88 as a quarterly as compared to between $6,000 and $7,000 as an annual.

Editorial work has increased because more papers have been handled and because the two-column format requires more time for making up page proof. The sections on Shorter Papers and Notes and Book Reviews are now included also. At present it is estimated that the job of editor is at least a half-time job and associated stenographic work about a quarter-time job. In addition, much time is donated by associate editors in reviewing the manuscripts.

I have now been editor of the *Transactions* for 3 years and feel that I have served my term. I am therefore resigning as editor upon the completion of Volume 88 and will pass the backlog of material on hand along to the new editor of Volume 89. The work has been time consuming but enjoyable and has been educational both to myself and, I hope, to the authors. If we on the Editorial Board have trod on the toes of some of the members of the Society, we beg their pardon. We have had a duty to perform in seeing that the *Transactions* contains articles with something important to say and that it is said in a concise and understandable fashion.

In conclusion I want to thank the hard-working associate editors, all of whom have given many hours of their time for reviewing papers. I want to thank the officers of the Society who have given the Editorial Board all possible cooperation and aid. I get the impression I have been playing in a really big

league team these last 3 years and it has been a pleasure. Lastly I want to thank the authors and other members of the Society who have gone out of their way this past year to send in material for publication and help get the quarterly started. Without such help the job could not have been done.

Report of Finance Committee

George J. Eicher

The Finance Committee has undertaken two major studies during the past year. One of these concerned the proper investment of funds surplus to our current operating needs. The other involved the establishment of a permanent executive-secretarial position which would entail a dues increase.

Following rather comprehensive research into the securities and investment field, the committee recommended to the Executive Committee in March liquidation of our holdings of some $2,500 worth of utility stocks and reinvestment of them in a good mutual fund. Because the government bonds held are nearing maturity and will return a relatively high rate of interest during the balance of their life, it was recommended that these be held to maturity. Because of the fact that the rate of returns on government bonds does not provide enough increment to offset inflation, however, it was recommended that no further purchases of these securities be made. Instead, it seems wisest to increase our holdings of mutual funds should any additional surplus money become available.

Because two of the divisions of the Society had voted in favor of the executive-secretarial position and an accompanying increase in annual dues to $15, President Lawrence requested that the Finance Committee study this proposal and take appropriate action in advance of this meeting. It was decided that because this meeting would have a preponderance of men from the regions that had already voted in favor of the position, whereas the majority of the membership may or may not be in sympathy with this proposal, the feelings of the entire body should be ascertained in advance of the meeting. This procedure would permit those present to vote intelligently with a knowledge of the feelings of the membership at large.

As was outlined in the July 1959 *Newsletter*, the Finance Committee feels that the executive-secretarial position should be established, but only after a period of study to find out just what type of person should be engaged, to develop a position description, to determine the scope and duties of the job, and to make adequate preparation to insure that the move will be a success. Some of the things we feel sure are desirable include better service to the membership in the form of more frequent newsletters containing information that only a full-time editor could develop, professional registry of members, representation of the Society nationally, better management of meetings, and perhaps more efficient utilization of funds. There are many other benefits to be derived from such a position, and, unquestionably, the Society has reached a stage where this is a highly desirable move. The period of study mentioned is to determine the proper way to develop the points mentioned above and not to decide whether or not the position should be established, as some seemed to interpret it.

Another point that needs some study and consideration is the possible effects of an increase in dues on the membership. We would not be able to maintain a national office at the $15 annual dues figure mentioned if the membership diminished. Under the $10 annual dues voted last year, we have sustained a loss in membership approximating 15 percent.

It should be taken into consideration, however, that the defection in the previous year under the old dues structure was 5 percent, as was also the percentage of new members taken in this year. This obviously represents a normal turnover and should be deducted from the 15 percent figure of loss. A reduction of 10 percent was the figure generally anticipated last year when the dues increase was proposed.

It is entirely possible that we have lost the bulk of those who would drop out under any increase in dues. It is also quite possible that the increased prestige and stature that membership in the Society would give the professional under the proposed structure would insure that few would feel that they could afford not to belong. This result would mean an increase in numbers.

Another item involving funds not now collected concerns the charging of a registration fee of $5 at meetings. This charge seems to be normal for the majority of such gatherings. It would be a minor part of the expense of most members in attendance, and most of them would be able to obtain reimbursement from their employers. Most important, the sum collected would carry the cost of the meeting and put the burden of the meeting expense on those who attend. The Finance Committee feels that this move is logical and proper and recommends that steps be taken to initiate the fee.

The postcard poll asked the views of the membership on the two above-mentioned subjects dealing with money. In regard to the executive-secretarial position, the question was posed: Do you favor the establishment of the Executive-Secretary position? Three choices were provided: (1) Yes, now; (2) Yes, after a period of study; (3) No. The results were as follows: (1) Yes, now — 137; (2) Yes, after a period of study — 318; (3) No — 236; (4) Not definite or not marked — 18. The combined "yes" votes totalled 455 or 65.8 percent. A number of comments were written on the cards and some were accompanied by letters. Nine wished to go on record as voting "maybe." Three brought forth the idea of exploring the possibility of hiring an executive secretary jointly with the Wildlife Society. Four suggested the idea mentioned in the "memo to the members" in the July *Newsletter* — that we have lower dues for students and nonprofessionals. One man stated that he wished his name dropped from the membership in the event that the increase should be voted because there are other journals that cost less for better quality. One man wanted to accept advertising in the quarterly to meet costs.

Several have raised the objection that the dues increase would be felt most, and hence resisted most, by younger members who are junior in position and salary. This feeling does not seem to be the case from an examination of the poll names. The greatest reaction against the executive secretary and dues increase has been shown by older and higher-positioned members. E. A. Seaman has noted the same trend in the defections from dues paying in the past 2 years. Quite possibly, many who are now in later life and/or occupy higher positions do not feel that they have much to gain from a more dynamic American Fisheries Society, whereas the younger members are most willing to invest in building up an organization that can be the means of improving their professional careers.

Voting on the question of the registration fee was more one-sided. Those signifying "yes" totaled 545 or 79 percent, the "noes" added up to 119, and 28 failed to mark this portion of the card. One man objected to the sum involved as too high and thought $3 more within reason. One man suggested that the fee should be charged to those who do not attend in order to encourage attendance. Another wanted to charge only non-members.

The Finance Committee concurs with those who desire lesser annual dues for nonprofessionals and students. We have many such members who do much to boost the Society and who are proud of their membership, but it is doubted that many of them would wish to pay what amounts to a professional membership fee. This question, however, raises problems that require further study. Two of these problems are the manner of separation into professional status and the quantity of material and service which will be provided to those paying less. Can we afford to provide the quarterly for $5 per year? Perhaps the *Newsletter* would suffice for these members, or perhaps $10 dues would cover costs of all printed material. It may be that three degres of individual membership would be desirable. Some thought in this regard is required.

It has been brought to the attention of the Finance Committee that our bylaws require that reinstatement of delinquent membership involves paying up back dues. This requirement is not only inhumane in the case of those who may have dropped out because of unemployment, but it is also unrealistic. If enforced, as it has generally not been, few previous members would rejoin, particularly under the conditions of higher dues. A man who has not paid for a number of years and wishes to rejoin should be treated as a new member and welcomed with open arms. We recommend that the section of the bylaws treating this subject be rewritten to require no paying of back dues when a man rejoins the Society. Under the rule passed at the last Executive Committee meeting, members in arrears do not receive publications. They should pay arrears dues if they wish the volumes for the periods of nonpayment.

The question of the method of payment of annual dues has been raised by E. A. Seaman. He states that several who joined in the spring of this year are provoked that they are again being billed for the new fiscal year. This, of course, would happen to some no matter when the billing occurs unless they were fully informed at the time of joining on the time of annual billing. Alternatives to the present procedure are: (1) on the initial year billing on a quarterly basis, *i.e.*, paying only for the number of quarters remaining until the end of the fiscal year; (2) billing, as some organizations do, on the date of joining. Under the latter system, when a man joins on March 25, he is billed each succeeding year on March 25. One advantage to this method is that it spreads the work of billing out throughout the year. A variation is billing on the man's birthday. The Secretary also advises that fiscal-year billing is out of date and that we should study the possibility of calendar-year billing. The Finance Committee feels that such a study should be made. The Finance Committee also feels that a serious study should be made of the problem of increasing the membership. This is an old issue, but if enough thought is given to it, new approaches may be developed. We recommend that the President appoint a sessional committee to produce ideas that may bear fruit.

Report of Committee on Names of Fishes

Reeve M. Bailey

Unlike other committees of the Society, the Committee on Names of Fishes is not adapted to function effectively on an annual basis with a rapid turnover in personnel. Rather, it can serve most advantageously over a period of years with relatively long tenure of membership. Following many years of work, the first list of names was published in 1948. The Committee subsequently undertook reconsideration of some names on the list and made certain recommendations for change. In retrospect, however, this effort seems to have been inefficient, and the Committee believes that in the future its energies should be channeled directly toward the production of periodic revisions. Changes in knowledge gained through new research indicate a need for revision at intervals of about 10 or 15 years.

Plans for a second edition of the list were initiated in 1954. Since then the active work of revision has continued and last September I tentatively promised publication of the list by this time. Events have proved me overly optimistic, since it was not possible to iron out all rough spots until the Committee could meet last June. Since then a provisional draft of the list has been circulated for comments among a number of institutions and individuals who have shown especial interest.

The second edition is now completed and I have the privilege of submitting it to the Society. A year ago the Executive Committee approved printing of the list as Special Publication Number 2. According to this plan, copies will be distributed to all active members of the Society and a substantial overrun will be placed in the hands of the Secretary for sale.

The new list includes 1,882 entries, more than three times the number included in the first edition. Except in length there are few innovations. The preamble contains a set of criteria which form the basis for selection of names. The running list includes entries for classes, orders, and families. Within families, species are arranged alphabetically by scientific name. Indices to common and scientific names will provide page references to all entries. Authorities' names are included with the scientific names.

This edition, in addition to having increased coverage of species, makes a number of changes in common names from the earlier publication. These include species that have been placed in synonymy and those, the names of which were changed by committee action following appearance of the first edition. Many changes are relatively minor (*e.g.*, brook trout instead of eastern brook trout). Very few apply to fresh-water fishes and most of these have been announced previously (*e.g.*, walleye, northern pike, largemouth bass). The majority of changes involve Pacific species. The Committee has attempted to conform to predominant usage in that area, resulting especially in changes in names for certain rockfishes, flatfishes, and viviparous perches.

Most members of the Society will discover that one or another of their favorite fishes is, from their viewpoint, poorly named. Let me assure you that this same opinion is shared by

each of us on the Committee. Most disagreement stems from regional variation in usage and we have arbitrated conflicts to the best of our ability. The Committee has operated on the basis of majority vote to settle differences on both scientific and common names. Members of the Committee are probably more tolerant of decisions with which they disagree than some of you may be, because they have participated in the debates and understand the reasons why they were outvoted. I regret that choices of all names will not be satisfactory to all of you.

[Ed. note: The complete report, *A List of Common and Scientific Names of Fishes from the United States and Canada (second edition)*, Am. Fish. Soc., Spec. Publ. No. 2, will be published early in 1960.]

Report of Committee on Water Pollution

Clarence M. Tarzwell

The Water Pollution Committee of the American Fisheries Society has as its task: 1) a survey of pollution problems and control activities in North America, and 2) a tabulation of research projects on water pollution being carried out by governmental agencies, educational institutions, industries, and private organizations.

The procedures used in making these surveys have been described in last year's report. During the past year the questionnaires which are used for collection of data were revised in order to reduce the time necessary for completion by cooperating groups and to make the data more pertinent. In this survey data are requested on: 1) pollution sources and the relative importance of different wastes; 2) new legislation and regulations; 3) staff and facilities and recent changes in the program; 4) major accomplishments affecting fish life; 5) research projects; and 6) publications.

Last year a report covering the period 1955-1957 was distributed. This represented a fairly complete coverage of Canada and the United States. Since the completion of the first report data have been secured from 43 states and 6 provinces of Canada, covering the period 1958-1959. It is hoped that reports can be secured from all states and provinces before the report covering this latter period is released.

The data at hand have been summarized to gain a general impression of trends and developments. In general, there has been an increase in pollution-abatement activities. The staff engaged in these activities was increased in 22 states and was decreased in only two states. Research activities have also increased as 16 states report additions to staff and increased activities. However, seven states still report no research work in progress.

A summarization of reports on the relative importance of different wastes indicates that for the United States their ranking is as follows:

1. Sanitary sewage
2. Pulp and paper wastes
3. Chemical-processing wastes
4. Oil and oil-refinery wastes
5. Mining wastes
6. Milk-processing wastes
7. Food-processing and canning wastes
8. Metal-plating and metal-processing wastes
9. Textile-processing wastes

For Canada the rating is as follows:

1. Pulp and paper wastes
2. Sanitary sewage
3. Mining wastes
4. Food-processing and canning wastes
5. Milk-processing wastes

One province listed oil and oil-refinery wastes as second in importance, while another rated pollution due to the broadcasting of insecticides as the number one problem.

These ratings differ somewhat from those reported for the first survey, 1955-1957. For this period the ratings were as follows:

1. Sanitary sewage
2. Textile-processing wastes
3. Pulp and papermill wastes
4. Plating wastes
5. Mining wastes
6. Oil and oil-refinery wastes
7. Chemical production
8. General food processing
9. Metal processing
10. Milk processing
11. Tannery wastes

While the order of importance has changed somewhat the wastes are the same. It would appear that there is a tendency for an increase in pulp and paper, chemical-processing, and oil-refinery wastes. It is certain that the petrochemical industry is growing rapidly. Further, wastes from this industry are very variable, are not well known, and many are quite toxic.

As in the first survey sanitary sewage was the most widespread pollutant and a problem in more states and provinces than any other waste. In this regard oil and oil-refinery wastes ranked second and pulp and paper-mill wastes third, in the United States. Other important classes of wastes in the order of their widespread occurrence are: chemical production, mining wastes, food-processing wastes, milk-processing wastes, textile-processing wastes, and metal-plating wastes. Two states listed silting as a problem and one listed radioactive wastes.

A complete report on pollution conditions, pollution abatement, and research in water pollution is now being compiled. Completion of the report awaits information from seven states which have not yet submitted their data. A great deal of data is at hand which should be of considerable interest. It is believed that the list of recent publications will be of interest and value to workers in the field. The final report will be mimeographed and will be available to interested persons.

Report of Committee on Commercial Fisheries

E. S. Iversen

The Committee will consider the highlights of the 1958 commercial landings, and developments or innovations in the pursuing, capturing, processing, and marketing of fish and fish products. This will be done for United States, Alaska, Canada, Mexico, Hawaii, and Puerto Rico. Data from the latter three areas are scanty. The information used in this report was taken from several sources. A concise summary of commercial fishery activities in the United States during 1958 was compiled by E. A. Powers, *Fisheries of the United States and Alaska, 1958 (a preliminary report)*. A considerable portion of the present report was taken from that summary. A discussion and summary of the 1958 commercial fishing of Canada appeared in the *Trade News*, an organ of the Canadian Department of Fisheries. Much of that summary is included here.

Before discussing the various areas, an interesting and important conference which was held during 1958 should be mentioned. The United Nations-sponsored conference on the Law of the Sea, held at Geneva, Switzerland, resulted in the adoption of four international conventions. These conventions are: (1) general regulations on the high seas, including prevention of pollution by radioactive wastes; (2) regulations covering the conservation of high seas fisheries; (3) regulations relating to the continental shelf; and (4) the optional protocol dealing with the compulsory settlement of disputes regarding fishing rights. It is felt that the conference completed some very significant work and laid the basis for further advances in the future.

UNITED STATES AND ALASKA

The yield of the commercial fisheries of the United States and Alaska in 1958 amounted to 4.72 billion pounds valued at a record-high $370 million to the fishermen. When compared with the 4.78 billion pounds valued at $351 million taken in 1957, the catch was down approximately 62 million pounds or 1 percent in volume but showed an increase in value of about $19 million, or 5 percent.

There was considerable variation in the catch of fish throughout the year, with the larger landings of most species occurring during the summer months. Landings during the 4-month period from June to September inclusive, accounted for 63 percent of the 1958 catch. During 1958 the commercial catch of fish and shellfish landed at ports on the Atlantic Coast amounted to 53 percent of the United States and Alaska total. Pacific Coast states accounted for 19 percent; the Gulf states, 17 percent; Alaska, 8 percent; and the Great Lakes and Mississippi River areas, 3 percent.

California's record pack of tuna in 1958 was produced from 229,086 tons of fish, of which the domestic fleet produced 157,067 tons, while 72,453 tons were imported. These figures on imports are concerned only with fresh and frozen fish and do not take imports

of canned tuna into consideration. The 1958 imports ran far ahead of the 53,651 tons from foreign sources in 1957; and the imports also had a sharp gain in the share of the total supply as well as in quantitative tonnages.

A phenomenal catch of bluefin was made by the purse seiners late in the summer.

For 1958 as a whole, the California landings of domestic albacore were 12,633 tons, including a substantial tonnage caught off Oregon but landed in Southern California. This compared with California landings of 18,888 tons in 1957, a decline of 6,255 tons, or about one-third.

Alaska's salmon pack, taken as a whole, reached about 3 million full cases in 1958, above a half-million better than in the previous season. The sharp decline in reds, however, tended to pull the value down. Western Alaska, with only 433,121 cases pack, of which only 278,434 were reds, was the weak spot. Only the Nushagak had even fair fishing, and its surprising pack of more than 60,000 cases of pinks was all that saved 1958 from pressing 1951 for post-war low. Central Alaska, supported by the Prince William Sound surprise in pinks, showed up well with its 1,343,000 cases above the 10-year average. Southeastern Alaska also squeezed out a narrow margin over the average, but it must be recognized that the average of the last decade is a long way below the longer-term mean for each of these districts.

Richest — but not the largest — salmon pack in Puget Sound history was canned in 1958. The pack was worth $23 million, actually $10 million more than the great pack of 1913. Proportion of sockeye in the total pack was as large as in any year, perhaps larger; this went along with inflation in running the value to new peaks. Of the sockeye run to the Fraser, perhaps half passed down Johnstone Strait outside of international convention waters, the catch from which is shared equally between Canada and the United States. Thus in 1958, out of a total run of 19 million sockeye, the American fishermen got only a little over 5 million fish, while the Canadian catch was fully twice as large.

A trend toward concentration of Pacific Northwest salmon canning on Puget Sound and the Columbia River continued to be manifest in 1958, with the pack of the coastal districts nominal, although more than twice that of the previous year. This step-up in volume to 6,690 full cases resulted from the production of an increased volume of chums and a slight lift in chinooks. Bluebacks, on the other hand, amounted to barely one-third of the amount which was canned the year before. The blueback pack of 833 cases in 1958 was the smallest for this species since 1953, and was a long way below the 5,076 cases packed in 1956.

With catch and pack approximately five times as great as in 1957 and by far the best in any year since 1951, the California sardine industry in 1958 took a long stride upward toward the heights it occupied so long as America's greatest fishery in point of tonnage. The catch exceeded 100,000 tons, against 20,000 in 1957 and only 2,620 tons in 1953. In its heyday the fishery consistently produced 500,000 to 600,000 tons a year. Canned pack was up to 2,256,000 cases, comparable with the average amount canned in pre-war years, but much less than half the all-time high pack of 5,430,000 cases produced in 1950. Unlike the previous year, there were no serious labor or price disputes and the southern fleet put to sea promptly on the opening day of the season. Most of the fish taken came from the Santa Cruz Rosa area. Comparatively few sardines were caught in the Monterey or San Francisco areas. Approximately 75 percent of the sardines processed in the San Francisco and Monterey plants were trucked in from the south.

The 1958 catch of Pacific halibut amounted to 47.9 million pounds valued at $7.6 million to the fishermen. Compared with the catch taken in the previous year, the 1958 production was down 4 percent in volume but showed a substantial rise of 16 percent in value. The overall average price-per-pound paid for halibut increased from 13.1 cents in 1957 to 15.9 cents in 1958.

Beside the early Westward season, a feature of the 1958 regulations was the opening to fishing of the "nursery grounds" in the Timbered Islet and Masset areas, which had been closed to fishing since the first halibut treaty went into effect in 1924. That treaty provided specifically for the closure of these two areas, believed to be marshalling grounds for halibut of sub-commercial sizes. Whether that was ever actually the case is not plain, but the fish taken by the fishing on these long-closed banks in 1958 proved to be approximately normal in their size distribution.

Total landings of menhaden in 1958 amounted to 1.5 billion pounds. This was about 145 million pounds or 9 percent less than the 1.7 billion-pound production of the previous year and considerably below the 2.1 billion-pound record catch taken in 1956. Compared with the 1957 landings, the New England catch in 1958 was 57 percent less and the Middle Atlantic production was 36 percent lower. Although there was a 16 percent increase in landings in the Chesapeake area, 20 percent in the South Atlantic area, and 18 percent in the Gulf area, the increases were not of such magnitude as to overcome the lower production from the more northern areas.

The 1958 menhaden catch in New England waters was down. The fall "run" of large fish in southern Long Island waters was disappointing. In past years these fish occurred in this area in very large schools and provided good fishing. In contrast to the reduced catches in northern waters, the fall fishery off the North Carolina coast proved to be exceptionally good.

Reflecting the abundance of sardines in 1958 were the sharply reduced catches of anchovies and jack and Pacific mackerel. Fishing for these species is done largely by the sardine fleet which in 1958 concentrated on the larger tonnage potential, the sardine. As a result, mackerel and anchovy fishing drifted to a low level. Compared with 1957 the anchovy catch was down 31.3 million pounds, jack mackerel suffered a decrease of 59.2 million pounds, and Pacific mackerel production was off 34.9 million pounds. The lack of fishing interest in mackerel was not entirely responsible for the decreased catches. Mackerel appeared to be less abundant in California waters than in 1957. Canners of anchovies also had some trouble in that the 1958 average size of the fish was generally too small for canning.

The 1958 shrimp catch amounted to approximately 209.2 million pounds valued at $73 million. Taken mainly in waters of the Gulf of Mexico and off the South Atlantic and Pacific Northwest states, shrimp provided the greatest revenue to United States fishermen in 1958. The Gulf of Mexico was the major shrimp-producing area and accounted for 82 percent of the volume and 87 percent of the value of the total 1958 shrimp catch. The Gulf of Mexico yielded more shrimp in 1958 than in the previous year, due in part to the white shrimp being more abundant in the North Central Gulf area. Landings along the South Atlantic coast were less than in the previous year.

Pacific shrimp canning was up from nothing in the spring of 1957 to a production of 142,000 cases, valued at $2,276,000 in 1958. In that time the business had spread from the first canning operation at Westport, Washington, at the entrance to Grays Harbor, south into California and north into Alaska, running as far west as Kodiak Island.

The recent development of machine pickers will materially affect production and landings in Alaska. Production of California ocean-caught shrimp has increased every year since 1952 when the fishery was first started, and the 1958 production was 1,700,000 pounds. This compares with a catch of 200,000 pounds when the California shrimp boats first started out in 1952.

The American Pacific canned crab pack of 1958 was 102,822 cases, of which 47,754 cases were king crab. The overall value of the pack was $2,596,362.

Growth trend of the Pacific oyster industry faltered in 1958. Operators have no hesitancy in ascribing this condition to the pressure of rising imports of canned oysters from Japan, whose shipments to the United States showed a marked increase over the preceding year. Washington state oyster production in pounds for 1958 was 9,880,266, as compared with 9,980,708 pounds in 1957. The decline was due to a sharp decrease in production in Grays Harbor, down nearly 250,000 pounds from 1957. The Olympia oyster production is low in comparison to past years, but at 30,430 pounds it is nearly twice as high as the record low in 1957.

Herring production in Maine and Alaska during 1958 totaled 171 million pounds and 89 million pounds, respectively. Compared with the 1957 production the Maine catch was up 11 percent in volume while landings in Alaska were down 25 percent. Maine canners, processing these fish as sardines, produced nearly 2.1 million standard cases. The Alaska herring reduction fishery failed to maintain its upward trend, the total catch falling to 41,788 tons. Although the catch in southeastern Alaska was excellent (36,185 tons) and above the long-term average for the past quarter cen-

tury, Prince William Sound and the Kodiak District produced the poorest catches on record (3,892 and 1,711 tons, respectively).

Landings of groundfish and ocean perch, which support the New England fillet industry, were about 5 percent above the previous year. Haddock were not so plentiful as in 1957. The catch (119.5 million pounds) was down approximately 14 million pounds. With haddock production down receipts of pollock increased. The 1958 catch was almost 11 million pounds above that of 1957. Landings of ocean perch in 1958 were 15 million pounds greater than in 1957. Unlike in the previous year, there were no price or labor disputes in this fishery during 1958 which resulted in an increase in fishing effort.

The 1958 United States production of fillets from groundfish and ocean perch amounted to 99.1 million pounds. Imports of groundfish and ocean perch fillets increased to a record 163.0 million pounds in 1958 making up 62 percent of the total domestic supply of these fillets.

The United States production of fish sticks in 1958 amounted to 60.9 million pounds valued at $26.8 million to the processors. This production was nearly 7.8 million pounds above that produced in 1957.

A total of 248 thousand tons of fish meal was produced in the United States and territories during 1958. This production was about 16 thousand tons less than that of the previous year and 48 thousand tons less than the record production of 296 thousand tons produced in 1956. The domestic production of fish meal was down due mainly to a drop in the catch of menhaden.

The pack of canned fishery products in the United States and territories totaled nearly 34.5 million standard cases valued at $388 million to the packers. This represented an increase of 11 percent in volume and 15 percent in value compared with that of the previous year.

The 1958 production of frozen fish and shellfish in the United States and Alaska totaled 322.2 million pounds. Of this amount, salt-water fish comprised 54 percent; shellfish, 28 percent; bait and animal food from both fresh- and salt-water fish, 17 percent; and fresh-water fish, the remaining 1 percent.

The United States production of fish portions in 1958 amounted to nearly 21.8 million pounds valued at about $8 million to the processors.

The per capita consumption of fish and shellfish in the United States amounted to 10.4 pounds (edible weight) in 1958, slightly above that of the 2 previous years. Consumption of fresh and frozen fish remained the same as in 1957, although less than in 1956, while that of canned products registered a slight increase. Consumption of cured products during 1958 is estimated to have been 0.6 pound per capita, the same as in the previous 2 years.

Experiments in metering a sodium hypochlorite solution to the sea water employed in washing the fishing vessel's hold and in washing the gutted fish on the vessel have proved to be highly successful during 1958. Voluntary United States standards of quality and condition for frozen fish blocks became effective in 1958. Standards for frozen, raw, breaded shrimp, and for frozen precooked fish sticks were also issued. The standards were developed by the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, in collaboration with industry technologists and the National Fisheries Institute under contract with the Bureau. The Department of Agriculture will offer, on a fee basis, inspection and certification service based on the standards.

During 1958 loans to fishermen continued under the U. S. Fish and Wildlife Service fishery loan program. These loans can be made only for the financing and refinancing of operations, maintenance, repairs, replacement and equipment of fishing vessels and fishing gear, and for research into the basic problems of the fisheries in cases where the credit applied for is not available elsewhere on reasonable terms. During the year many new boats were documented. A breakdown of first-vessel documentation by area shows the Gulf Coast, the South Atlantic, and the Pacific states with well-established leads. In 1958 the Gulf Coast area documented 40 percent of the total of 685 new boats; 20 percent of the total was documented in South Atlantic states; and 16 percent in Pacific states.

A considerable number of exploratory fishing and gear research investigations were carried out by exploratory fishing vessels of the United States Bureau of Commercial Fisheries

during 1958. One exploratory fishing program in 1958 was concerned primarily with shrimp exploration of the northeast coast of South America and investigation of midwater and surface school fish potentials in the Gulf of Mexico. Efforts to adapt heavy-duty, New England style fish trawls for snapper trawling in the Gulf of Mexico met with considerable success. A red snapper trap program involving the study of various conventional and experimental fish traps and reactions of fishes to them under actual fishing conditions was undertaken.

The shrimp program included, in 1958, explorations off the coasts of Oregon, Washington, and central Alaska. During the year commercial quantities of pink or "cocktail" shrimp and larger varieties such as side-stripe and coon-stripe were located in the bays and inlets of Kodiak Island, Lower Cook Inlet, and along the southeast side of the Kenai Peninsula.

Bluefin tuna were landed at two exploratory longline stations during a mid-April to mid-May cruise of the *Delaware* to investigate the pelagic offshore resources of the western North Atlantic. Significant concentrations in the distribution of yellowfin and bigeye tuna were found and the most productive area was south of Georges Bank. One major activity of the Bureau of Commercial Fisheries program was further development and testing of an air-bubble curtain for successfully driving schools of herring from areas inaccessible to conventional gear into areas that are accessible to conventional gear.

Trade journals listed important developments in gear and equipment for fishing vessels which involve new materials for standard equipment, such as polyethylene rope or plastic pipe. Many innovations such as double-rig trawling for shrimp, the use of the power block in handling gear on seiners, and improved rigs for midwater trawls were used by more fishermen in 1958. Some new developments were: the nylon and the variable-pitch propeller, an improved "lift-deck" for scallop boats, and a trend to seawater chill units to replace icing on West Coast trollers and halibut boats. It might be well to mention another important matter: the state-federal education programs for training both apprentice and experienced fishermen. These schools have been in operation in coastal states for several years. During 1958 new schools started and existing programs were expanded.

CANADA

Cod landings from all areas were down 131 million pounds or 22 percent from the previous year and the decline in the haddock catch, also 22 percent, amounted to 14 million pounds. Because of higher unit prices, however, the decrease in value was only 17 percent in the case of cod and 4 percent in haddock. Other similar species seemed to be present on the Banks in their usual quantities. They produced catches which were relatively small but which this year increased under heavy fishing; the pollock, hake, and cusk by 20 percent; redfish by 30 percent. Thus the total catch of cod and other species just mentioned declined by only 16 percent in quantity and 10 percent in value.

With flatfish added, total landings of all Atlantic groundfish were less than those of the previous year by 14 percent in quantity and 9 percent in value. The halibut catch was 17 percent smaller, but rather because rough weather interfered with longlining than because of any apparent scarcity; and fishermen's income from this source remained about the same. Plaice and greysole were less plentiful than in the previous year, small mixed flatfish more plentiful.

The groundfish industry in the Maritime Provinces suffered less from the cod scarcity than plants in Newfoundland. A good run of cod in the Gulf of St. Lawrence during the summer had been intensively fished. Also, with better supplies of other groundfish, the three more southerly provinces are always less exclusively dependent on cod. Their overall production of fresh and frozen products was maintained at normal levels. Their salting industry, however, reflected the reduction in supplies of saltbulk fish from Newfoundland.

Throughout the fall many fresh fish plants in both the Maritime Provinces and Newfoundland operated at less than capacity for lack of supplies. The market for fresh and frozen fish, fillets, and blocks had been good all summer and improved in the autumn. Shipments of haddock fillets and blocks dropped by 40 percent, reflecting the scarcity of this species, but a larger than usual proportion of available cod was diverted to freezing and to-

tal exports of fresh and frozen groundfish products actually declined by only about 2 percent. With rising prices their dollar volume expanded somewhat. The end of the year saw the beginning of bonus prices when fleets out of ports in the Gulf of St. Lawrence began to lay up for the winter and plants with backlogs of unfilled orders offered extra payments to keep them fishing. By January 1 the larger firms throughout the Atlantic Provinces were offering premium prices for fancy quality fresh fish. The salting industry was more crippled than the freezing industry by scarcity of cod. Newfoundland produces most of the supply for salting and it was there that the fishery had failed. Because of this known failure, foreign buyers began even in December to secure supplies for Lenten sales. In spite of efforts to meet this unusually heavy year-end demand, salting plants fell behind their previous year's shipments.

Halibut had been plentiful during the spring fishery, which opened in May. In spite of bad weather on the fishing grounds, the catch had almost equalled that of the previous year and with markets steadier and prices higher its landed value had been greater by about $1 million. The fall season consisted of 2 weeks of fishing in Hecate Strait in September. Results were about average and in terms of fishermen's income the lead over the previous year was maintained.

Pacific groundfish landings were light for various reasons. Early in the fall fishermen were preoccupied with salmon. In November individual trawler catches were considered good for the time of year but weather permitted very little fishing. By December receipts at Vancouver had dropped so low that local firms were importing fillets from the United States for the domestic market.

The lobster, herring, and smelt fisheries were active through the fall. A profitable lobster season in Northumberland Strait closed early in October. The Bay of Fundy opened soon after and at the beginning of December the open area was extended around southern Nova Scotia to Halifax. Very high landed prices encouraged intensive fishing early in the fall and induced many lobstermen to leave their gear in the water during the stormy later months. Trap losses consequently were rather heavy. Initial catches were excellent in newly opened areas. Although, as usually happens, landings dropped rather steeply after the early heavy catches, the total fall catch was heavier and much more valuable than in 1957 and, after a rather disappointing summer, brought May-December figures almost up to those of the previous year in quantity and well ahead in value.

Herring fishing was poor in the Gulf of St. Lawrence in September but excellent off southern Nova Scotia in October. By November catches were dropping, weather was unfavorable, and fishermen's attention turned to preparations for winter lobstering. With a good demand for herring all fall at bait freezers and pickling plants, landed prices were higher than in the previous season. Canned sardine production was at the low level normal for the latter months of the year, with adequate canned stocks on hand and shipments going out regularly to meet steady market demand.

Early heavy ice formation in Northumberland Strait favoured the smelt bagnet fishery and the catch to the end of December was considerably ahead of the previous year.

In Newfoundland, where cod provides by far the largest and most valuable catch, the scarcity of this species created serious problems. The cod trap fishery, after a good beginning, ceased at the end of July when the schools moved offshore much earlier than usual. Fishermen then turned to the trawl fishery, which was a failure. Non-appearance of squid resulted in severe shortage of bait but the cod failure was due to the shortage of fish on the grounds.

With an excellent summer market more freezing plants opened than in 1957. Production of cod fillets and blocks increased slightly and output of redfish, plaice, and greysole fillets expanded substantially. Prices rose a little and remained firm through the fall.

Heavier frozen production left little cod for saltfish, production of which fell off by 35 percent (light dry weight basis) to the lowest output on record. In Notre Dame and Bonavista Bays less than half as much was produced as in 1957. On the Labrador coast where fishing was much better but weather much worse than elsewhere, output of salted fish dropped by only 10 percent. Although there was a halt this year in expansion of Newfoundland's mechanical drying facilities, there was a further increase in the proportion

of saltbulk dried on the Island. Shipments of saltbulk to the Canadian mainland declined considerably.

In spite of a substantial carryover from 1957 production, demand for light-salted fish exceeded the supply. This maintained export prices and brought prices to fishermen gradually up to the previous year's levels. Brazil came back into the salt fish market during the fall after an absence of several years. Stocks on hand at the end of December were very much smaller than a year earlier and it was plain that there would be no significant carryover into the 1959 fishing season.

The fall herring fishery on the west coast yielded a much smaller catch than in 1957. Large schools of herring were present, but often in locations where seining was difficult or impossible. Windy weather and early appearance of ice on the fishing grounds were further adverse factors. Markets were steady for both pickled herring and bait.

The mackerel fishery was a failure. Seventy-seven barrels of pickled mackerel fillets were produced, compared with 710 barrels in the previous year.

Atlantic salmon landings increased by 5 percent but their value by only 2 percent, as lower prices were paid on the Labrador coast and on the southern shore. About 80 percent of the catch was marketed fresh or frozen. there was a substantial increase in output of pickled salmon, and the balance was canned.

Lobstering was on the whole more successful than in 1957, with heavier landings on the east and south coasts more than offsetting a slight decline in yield of the important west coast fishery. Most of the lobsters were exported alive to the United States. Experimental use of wood shavings for packing for air transport gave promising results. Production of canned lobsters continued to decline. As already indicated in relation to groundfish, the squid fishery was a complete failure.

Turbot landings increased by half in value and by more than half in quantity. Most of the catch was taken in western Notre Dame Bay, one of the areas most seriously affected by the cod scarcity. Following the usual routine, the fish was pickled and shipped to the Canadian mainland. Although the average of landed prices had dropped, reflecting the heavy catch, there was a steady market for the pickled product and those shipments saved a considerable number of Notre Dame Bay communities from destitution.

Decline in Newfoundland's forest industry in 1958 caused an increase in the number of men who engaged in fishing. The meager returns of the latter industry therefore had to be divided among more persons so that the average of individual incomes was very low. When the bait shortage became apparent, the federal Department of Fisheries cooperated with the larger fishing firms to locate, import, and distribute bait from Nova Scotia, California, New England, and Europe. At the time, this bait only proved that the cod scarcity was real and continuing.

For Pacific fishermen 1958 was a banner year. The salmon pack amounted to 1,908,000 cases of which 1,079,000 cases were sockeye, while pinks accounted for 456,000 cases and chums for 229,000 cases. The sockeye pack was just short of the all-time record. The United Kingdom lifted currency controls from its salmon imports September 18 and on the following day British interests bought the entire sockeye pack, except 300,000 cases reserved for the domestic market, for $26 million. The salmon fishermen's gross income was estimated at between $35 million and $36 million, about double the 1957 figure.

The salmon seine and gill-net fisheries closed in October but chum salmon were still so plentiful on the fishing grounds in November that brief re-openings were permitted. Largely because of bad weather, results were poor. The weather also brought a continuing light salmon troll fishery to a virtual standstill.

A record summer herring catch of 85 million pounds landed in 1957 was far surpassed last summer when a spectacular new record of 142 million pounds was established. As usual, the fleet tied up for a 2-week period in October and then started the winter fishery. Record landings continued. Herring, which are fished under quota control, were so abundant that many local quotas were extended. By December rough weather in Hecate Strait seriously hampered seining, but before operations were broken off for the Christmas holidays the vessels had landed a further 202 million pounds. Most of the Pacific herring catch goes to reduction plants, which sometimes operated round the clock to keep up with receipts. Markets for both herring meal and herring oil were rather slow.

Shellfish were in good demand throughout the fall months and markets strengthened as the holiday season approached but weather was consistently unfavorable to these fisheries, especially on the west coast of Vancouver Island, where they are normally active. A shrimp trawl fishery in the Nanaimo-Ladysmith area was one of the more successful efforts.

Clam production in British Columbia showed a decline in 1958, with the province's total yield of clams counted as 2,300,000 pounds, all varieties. Of the 1958 yield it is estimated that approximately 90 percent were hardshell clams. Razor clams, produced almost altogether in the Queen Charlotte Islands, were counted as only 164,000 pounds in 1958, down from 187,000 pounds the year before.

The course of clam production in British Columbia ran opposite to that of crabs and shrimp, the major shellfish items, although it followed in a measure the decline manifest in oysters, where there was a decline of 6,400 gallons to a yield of 62,000 gallons, most of it from the bed operated by British Columbia Packers, Ltd., in Boundary Bay.

It was a big year for whaling off the coast of British Columbia in 1958, probably the biggest on record by a substantial margin. A total of 774 whales were killed by the chaser boats of the British Columbia Packers fleet, operating out of the Coal Harbor base in Quatsino Sound. This figure compares with 635 whales caught in the previous season and tops all previous kills by British Columbia Packers' vessels. In the early days of whaling off British Columbia the annual whale harvest was seldom more than 400 in a season.

The use of refrigerated sea water for the preservation of fish can now be adapted to small fishing vessels. A Fisheries Research Bureau of Canada report describes installations in two steel vessels built in British Columbia during 1958.

HAWAII

Hawaiian fisheries in 1958 moved toward the solution of three problems which promise most for stability and extension of the industry: (1) the live bait shortage; (2) continuity of cannery fish supply; and (3) increased effectiveness of vessel operation. Two years of below normal catches of the oceanic skipjack on which the industry primarily depends pointed up the necessity for a vigorous attack on the problems which have handicapped the mid-ocean operations in the past. This work is being done by U.S. Fish and Wildlife Service and Hawaiian tuna packers.

PUERTO RICO

Puerto Rico's tuna canning operations are expected to advance sharply with the completion of the new cannery being built by Star-Kist Foods, Inc., at the west end of the island. This will give Puerto Rico a second large tuna plant, in addition to the National Packing Co., a Van Camp subsidiary, at Ponce. A substantial tonnage of Atlantic tuna, most of it caught by Japanese vessels, was transshipped and transported to Puerto Rico during 1958.

MEXICO

The year 1958 presented a picture of growth and constant fishing-fleet modernization. This is true of Mexico's boat-building industry on both coasts, for upwards of 150 new shrimp boats were under construction during the year. A drive was begun in 1958 to create for the nation a real merchant marine and the fishing industry has a part in the program. Another significant development is the planning for more large building and repair ways to handle bigger vessels.

Report of Committee on Hydrobiology and Fish Culture

I. B. BYRD

The work of the Hydrobiology and Fish Culture Committee during 1958-59 was divided into three main categories: (1) assisting program chairman in arranging papers on fish toxicants and hormone spawning of warm-water fishes; (2) analyzing some of the values of controlling fish populations by chemicals; and (3) reporting new discoveries and developments.

USE OF FISH TOXICANTS IN FISH MANAGEMENT

Fish toxicants are used widely in fish management. Therefore, this Committee has attempted to analyze some of the values of controlling fish populations. It appears that the

killing and rearing of fish are quite compatible procedures for obtaining the greatest benefit from our sport fishery resources. The present methods of reducing or eliminating various components of the fish populations in lakes and streams are woefully inadequate.

Past efforts in using chemicals for the control of fish populations have emphasized complete eradication. However, the application of fish toxicants to waters in such a way as to deliberately cause a partial or selective kill of the fish present is probably the best use of this method of fish management. There are several advantages in partial kills of fish populations. Much of the over-abundance of natural reproduction of warm-water fishes can be eliminated through careful application of quickly-dissipating toxicants in shallow-water areas of lakes and ponds. Partial fish kills are usually followed by a period of very rapid growth of the remaining fishes. It is often superior to a complete eradication even when a complete kill is possible in that it does not take the lake out of production for 1 or 2 years. Complete fish kills may be necessary in some cases, however, to change the character of the fish population or to rid the environment of an unwanted pest fish.

Many chemicals, such as toxaphene or endrin, which would produce complete fish kills at a reasonable cost are known to be many times as toxic as the popular forms of rotenone now in use. Many of these fish killers have become known only through their accidental misuse in agriculture. Because of the potential value of these chemicals for fish management purposes, more effort should be expended by public agencies in determining their safe use as fish killers.

In many parts of the country streams furnish the bulk of the fishing opportunity, but little has been done to control undesirable fish populations in these areas. Electrofishing has more promise of catching fish in streams but chemical control would undoubtedly be superior to this method. Special, fast-acting toxicants are needed before the control of fish populations in streams ever reaches the state of development of that in lakes and ponds. Recent developments in the use of selective chemicals to control undesirable fishes, with special reference to the sea lamprey, offer promise that this method will eventually receive wide application.

In the process of screening some 4,600 chemicals, six mononitrophenols which were significantly more toxic to sea lamprey larvae than to other aquatic organisms were discovered. The differential toxicities displayed by the phenolic compounds and the destructive nature of these compounds on lamprey ammocoetes point to the use of selective chemicals as a promising approach of control of undesirable fishes.

TRACING OF SEDIMENTS WITH RADIOACTIVE ISOTOPES

A new technique developed in Japan has been adapted by the University of California and the United States Corps of Engineers to determine the rate of sedimentation in San Francisco Bay. A known quantity of a radioactive isotope of gold, used as a test tracer, is placed in the waters of San Francisco Bay. The isotope, when mixed with Bay mud, adheres closely to it and the mixture behaves similarly to the silt load carried by Bay waters. As the silt load is deposited, the area where it might be found is surveyed with an underwater detector. By measuring the isotope activity concentration with the specially designed detection equipment, the rate of sedimentation and its dispersion from a given point can be determined. The method holds promise as a biological technique for measuring environmental changes affecting fish populations.

STUDIES OF BASIC PRODUCTIVITY OF LAKES USING TRACE ELEMENTS

The carbon-14 technique is a recently developed experimental method for determining basic productivity, or the production of organic matter by microscopic plants through the process of photosynthesis, by measuring the rate of assimilation of radioactive carbon (C^{14}) by the plants. Essentially, the method which is being tested by the University of California consists of adding a small quantity of radioactive carbonate, $C^{14}O_3^{=}$, to a sample of water containing its natural plankton population. After allowing photosynthesis to proceed for a suitable period, the plankton is filtered, washed, and dried, and its activity is measured by standard counting techniques. The rate of radioactive carbon uptake is used as a measure of the productivity of the water.

Periodic sampling of natural waters by the above technique has shown that fluctuations in

productivity may occur during the course of a year. Simultaneous chemical analyses of such waters have demonstrated that periods of lowered productivity have coincided with temporary, seasonal deficiencies of one or more trace elements, such as cobalt. Therefore, the addition of minute quantities of the temporarily deficient trace elements at the time of year when needed may be expected to increase the over-all productivity of a water and consequently produce a greater yield of fish.

INTERMINGLING OF ASIAN AND AMERICAN STOCKS OF PACIFIC SALMON AND ITS SIGNIFICANCE

The research conducted by the member nations (Canada, Japan, and the United States) of the International North Pacific Fisheries Commission has uncovered many facts which previously were theoretical or unknown. These discoveries include the distribution of North American and Asian salmon in the North Pacific Ocean, migration patterns, food habits, ecology, and growth. "Sockeye, pink and chum salmon of Asian and North American origin intermingle in a broad area in the North Pacific and the Bering Sea, apparently extending over at least 30 degrees of longitude between 170° E. and 160° W."[1] Methods used to differentiate the stocks included techniques in serology, morphology, scale analysis, advanced statistical methods, oceanography, and parasitology.

MODIFYING THE MARINE ENVIRONMENT

California, Alabama, Texas, and possibly other states have begun experimental marine fish habitat development projects. California is evaluating its experiments by the use of divers. These projects deal with the placement and evaluation of artificial reefs or fishing banks. Old car bodies, old street cars, sunken barges, concrete blocks, and other objects have been used in the various areas tested. The objectives of these experiments are to concentrate fish and increase the angler harvest, just as brush shelters do in inland lakes. Reports on these projects have indicated a considerable increase in fish concentrations around the artificial reefs.

[1]International North Pacific Fisheries Commission Document 249, p. 59, 1958.

EXOTIC SPECIES

Two species of tilapia are being tested by the Fisheries Laboratory at Auburn, Alabama. These are *Tilapia nilotica*, native to north Africa, and *Tilapia mossambica*, native to Indonesia. These fish are being tested as a biological control of filamentous algae and certain underwater pond weeds. They also are being tested as sport fish alone and to supplement bluegill-bass populations.

The Israeli strain of common carp is in tests for biological control of *Pithophora* and certain pond weeds. Encouraging results in ponds stocked with this carp have been reported in Alabama and Georgia.

COMMERCIAL FISH FARMING

Commercial warm-water fish farming is currently being developed in the southeast on the results of experiments conducted by the Alabama Agricultural Experiment Station. Methods have been devised for raising per acre from 500 to 800 pounds of buffalo fish, 900 to 1,200 pounds speckled bullhead (red catfish), and up to 2,300 pounds of channel catfish. A new research station in Arkansas has been authorized by Congress to develop further commercial production of warm-water fish in ponds.

The channel catfish is also in tests in Alabama as both sport fish and commercial fish. The fish are fed to produce in excess of 1,500 pounds per acre and the pond opened to fishing as long as the fish can be caught readily. Subsequently the pond is drained and the remaining fish sold.

WEED CONTROL

Weed control is always a very important problem in water management. Dr. Lawrence, Alabama Polytechnic Institute, is currently testing hundreds of chemicals in an attempt to find new and better herbicides for aquatic weed control. He has devised a rapid method for screening chemicals for herbicidal activity under laboratory conditions.

A NEW TYPE OF FISH TRAPPING FACILITY

A unique fish trapping facility, where the fish do most of the work, is in operation on the Trinity River, California. The trapping facility was installed to preserve the salmon and steelhead runs in the upper Trinity River

while construction of the huge Trinity Dam is in progress. The trapping installation consists of a weir set at an angle across the river; this prevents the fish from traveling farther upstream. The weir is so built that its operation is not affected by stream flow conditions, even at peak spring runoff periods.

Just below the weir on one side of the river is a fish ladder. The salmon and steelhead ascend the ladder and pass into a holding tank 68 by 12 feet, with a water depth of about 4 feet. At the upstream end of the holding tank is an artificial waterfall created by water welling up between the holding tank and a 12- by 12-foot anesthetic tank. The waterfall is covered by a metal grill. The anesthetic tank holds about 1,500 gallons of water, to which is added 75 cubic centimeters of quinaldine.

Fish in the holding tank, jumping at the waterfall, suddenly find themselves in the anesthetic tank as they slither across a horizontal grill separating the two. At such times that the fish do not voluntarily jump at the waterfall, a gasoline engine power sweep is put into operation. This forces the fish over the waterfall and into the anesthetic tank where, seconds later, they become anesthetized and sink toward the bottom, which slopes three ways toward the end of a built-in escalator.

The fish are carried on the escalator from the tank to the top of a fish hauling truck. The tank truck is filled with clear, cool, well-aerated water and the fish revive within a matter of seconds. They are now ready for the ride upstream to the release site on the river about 16 miles above the construction zone.

MANAGED STATE LAKES

The construction of lakes by the Alabama Department of Conservation was initiated to provide fishing in those areas of the state having insufficient public fishing waters. The lakes were constructed on carefully selected sites so they could be fertilized and otherwise managed to provide high sustained yields of fish. The lakes were stocked with bluegill, redear sunfish, and largemouth bass.

Twelve state-owned lakes containing 841 acres were open to fishing for 2 to 8 years during the period of 1950-58 providing a total of 4,286 acre-years of fishing. During this time the lakes provided a total of 695,282 fisherman-trips in which the fishermen caught a total of 2,530,182 fish weighing 746,598 pounds. The average annual number of fisherman-trips per acre for all lakes was 162.2 and the average annual catch per acre was 590 fish weighing 174.2 pounds. The lakes provided a year-round fishery with satisfactory seasonal distributions of catch. Although a larger total catch was taken during the spring and summer, the catch per fisherman-effort was somewhat higher during the fall and winter. After an average first year catch of 223.9 pounds of fish per acre, the average yearly catch per acre remained relatively stable, ranging from 144.5 to 179.0 pounds per acre for periods up to 8 years.

Report of Committee on National-State Relations

RAYMOND E. JOHNSON

Work on National-State relations in the fisheries fields this year was based on the unusually complete report of the National-State Relations Committee for 1958.

That report showed two major areas of conflict between state and federal organizations dealing with fisheries subjects. One area was between the Corps of Engineers and seven eastern states where federal flood control projects involved the drainage of coastal marshes and river oxbows. The other was between seven western states, the Bureau of Reclamation, and the U. S. Fish and Wildlife Service. This conflict arose from different interpretations placed on reclamation laws.

All of the complaints were made by state conservation departments. No federal agency recognized or admitted that differing opinions constituted a problem. The eastern complaints were directed at the problems themselves, while the western complaints were aimed more specifically at federal agencies. It was apparent in last year's report that cloudy definitions of federal-state responsibilities in the field of water resource development were leading to misunderstandings.

In 1959 an effort was made to define these areas of responsibilities more clearly and to solve the major problems. The work was not completed, but some progress was made. The

problem was eased in the East by new legislation. Passage of the Fish and Wildlife Coordination Act of August 1958 strengthened the position of the fisheries agencies in their dealings with federal water-resource development bureaus, and did much to define federal and state responsibilities in this field.

Additional agreements went into effect between states and federal agencies, or between federal agencies alone, which also clarified the areas of respective responsibilities. In some cases the areas of friction reported by last year's Committee were discussed in meetings between the appropriate agencies. With a few important exceptions, the complaints of 1 year ago were based on misunderstandings or misapprehensions. In one instance the transfer of experienced fisheries personnel to a federal organization had left a bad impression on the former state employer. There is reason to believe that the tenor of relations between states and federal groups in the East is at an especially felicitous level.

Two new trouble areas appeared in the West in 1959. One is minor in nature on Indian reservations and possibly on military areas. Several tribal councils in the Southwest are developing hunting, fishing, and recreational resources on their reservations. They are charging fees of all non-Indians for the use of these facilities. If the Sikes Bill (H. R. 2565) is enacted by the 86th Congress, similar mandatory fees may be imposed for hunting and fishing on military areas. State conservation administrators would rather have the state licenses serve as the only mandatory permits, and have the Indian and military fees issued only on a permissive basis after agreement with the state organization.

The second trouble area is much more disturbing. In the administration of vast areas of public domain, the Bureau of Land Management has found it difficult to allow unrestricted public access to good hunting and fishing areas. The states also have made several efforts to withdraw certain lands from the public domain for hunting and fishing purposes. These efforts so far have met with failure even though state personnel and federal administrators have held several meetings to discuss the situation. No solution to the problem is apparent at this time.

Efforts made in the name of the Society to act as a mediator in complex national-state disagreements were most successful in the eastern states, and least successful in the western. It is recommended that these efforts be continued, however, on a few major problems each year where the Society can act as an impartial investigator and conciliator. This is a delicate undertaking, but the outcome usually justifies the risks.

Report of Committee on International Relations

Norman S. Baldwin

International co-operation in fisheries is continuing to expand with the development of bilateral and multilateral agreements among nations, such as the Convention for the Conservation of Shrimp recently ratified by Cuba and the United States. This Convention is designed to provide the means for joint and coordinated action by these two countries to develop and maintain the maximum sustainable production from shrimp resources of common concern in the Gulf of Mexico, off the coast of Cuba, and along the Florida coast of the United States. The responsibilities of other fishery commissions in which Canada and the United States hold membership have been outlined in previous reports and need not be repeated here.

In spite of much-publicized disputes over fishing rights in coastal waters, there appears to be a growing readiness among nations to negotiate difficult international fishery problems. The success of some 20 international fishery organizations has undoubtedly been a major influence toward improvement of attitude.

Growing knowledge of aquatic resources and improved methods of exploiting them will inevitably lead to their greater use. At the moment, although three-quarters of the surface of the earth is covered with water, only 10 percent of the animal protein consumed comes from the sea. Many nations with large populations and limited agricultural areas, such as Japan, have for centuries looked to the sea for most of their food and in recent years have developed their fishing fleets until fish products are now a substantial part of the national income. Other nations such as the U. S. S. R.,

sensing the productivity of the oceans, have recently developed large fishing fleets which are currently exploring the fish-production potential of remote areas.

A gigantic step from our location in Florida to Alaska would set us in an area where international fishery problems are multiplying. This year a Soviet fleet of 50 to 60 vessels, including tankers and refrigerator ships, was observed in the eastern Bering Sea. In this same area Japan has developed a high seas fishery for salmon, but has under the terms of an agreement with the United States and Canada abstained from fishing east of a provisional line arbitrarily established to separate salmon stocks of North American and Asiatic origin. The International North Pacific Fisheries Commission has developed an extensive research program, the results of which will help settle many of the important issues in this region.

The resources of the sea have long been the prize of the more technically advanced nations. However, undeveloped nations, eager to raise the living standards of their people, have shown a growing interest in their fisheries. Programs of technical assistance in fisheries have been established by the United Nations under FAO, the United States under the International Cooperation Administration, and a number of countries, including Canada, under the Colombo Plan.

The Fisheries Division of FAO has been a depository and clearing house for information on fisheries collected throughout the world. Its bibliographic service is familiar to many of the members. A very important service has been the identification of weaknesses in existing methods and practices in fishery biology and the organization of projects in cooperation with other agencies to overcome them. This year the Fisheries Division of FAO sent 44 fishery experts to 29 countries to assist them in developing marine and inland fisheries, managing existing fisheries, modernizing fishing methods, organizing statistical services, improving marketing and distribution facilities, organizing fishery cooperatives, and establishing research programs and training centers. The Division has also sponsored the training of some 25 nationals in foreign countries. During the past year FAO has convened meetings on a variety of subjects including the disposal of waste in the marine environment, fishery economics, fishery cooperatives, and the design of fishing boats.

The International Cooperation Administration sponsored the training in the United States this year of 20 persons from India, Indonesia, Israel, Korea, Pakistan, Thailand, and Viet Nam. A field force of 15 fishery experts, augmented by some term employees, administered projects in India, Liberia, Pakistan, Somalia, Sudan, and Tunisia.

The Cooperative Economic Development Plan for south and southeast Asia, known better as the Colombo Plan, includes a fishery technical cooperation program in which Canada participates by: (1) sponsoring the training in Canada of foreign nationals; (2) assigning experts abroad; (3) providing boats, special harbor equipment, and training facilities. Most of the assistance has been to Ceylon.

Last year the committee drew your attention to the Geneva Conference on the Law of the Sea, and the failure of the Conference to reach agreement on the breadth of the territorial sea. Another conference to deal with this issue is scheduled for March and April of next year and will be an event of more than ordinary significance. The committee would recommend to the membership a study of the Convention on Fishing and the Conservation of Living Resources on the High Sea adopted by the 1958 Conference, for it contains a philosophy for the settlement of domestic as well as international disputes where fish resources are used by two groups.

REGISTERED ATTENDANCE

EIGHTY-NINTH ANNUAL MEETING

Aaron, J. C., Virginia
Abedin, Zaynul, Alabama
Allen, J. Frances, Washington, D. C.
Allen, W. D., Florida
Allison, Don, Florida
Anderson, I. F., Arkansas
Andriano, Don, Utah
Aldrich, A. D., Florida
Alford, Julian R., Florida

Bailey, Reeve M., Michigan
Banks, F. G., Florida
Barkley, James, Mississippi
Barkuloo, Jim, Florida
Barrie, Leon J., Florida
Beal, G. E., North Carolina
Beames, G. H., Florida
Bell, T. F., Pennsylvania
Bender, Michael E., Illinois
Bennett, Vernon, Missouri
Benson, Norman G., Utah
Berger, C. R., Pennsylvania
Berger, Frank, Florida
Bevan, Mrs. Edith, Florida
Biggs, John A., Washington
Blosz, John, Georgia
Bogart, Maynard M., Pennsylvania
Bouldin, R. W., Tennessee
Bowers, Charles C., Kentucky
Bowles, Rollin E., Oregon
Briggs, Frank P., Missouri
Brown, John, Florida
Bryant, Dick, Florida
Buchanan, H. L., Pennsylvania
Burch, Ewart H., Missouri
Burgess, Joe E., Florida
Burkel, Donald, Missouri
Burwell, Robert W., Minnesota
Butler, Ted, Missouri
Byrd, I. B., Alabama
Byrd, W. Keith, Florida

Calhoun, Alex, California
Callison, Charles H., Washington, D. C.
Carlander, Kenneth, Iowa
Carter, Bernie, Kentucky
Carter, Jim, Florida
Cating, James P., Mississippi
Chappell, Undine, Florida
Christenson, Lyle, Wisconsin
Chun, Seung Kwan, Korea
Clark, Clarence F., Ohio
Clark, Minor, Kentucky
Clugston, James, Florida
Coates, Christopher, New York
Cochran, A. B., Florida
Cole, William C., Kansas
Coleman, Elvin W., Mississippi
Conder, John R., Tennessee
Connell, Bettye, Florida
Cook, A. B., Michigan
Cooksey, Ralph G., Florida
Cooper, Helen, Missouri
Copeland, J. B., Florida
Cornell, J. H., North Carolina
Costoplos, Helen, Florida
Cottam, Clarence, Texas
Cotte, Richardo, Puerto Rico
Cox, J. W., South Carolina
Cox, James J., Florida
Cox, Nelson, Arkansas
Crance, Johnie, Alabama
Crane, Harold, Utah
Cronan, John M., Rhode Island
Crum, Jim W., Florida
Cumbie, A. L. Jack, Florida

Dahne, Robert, Florida
Davis, Ronald, Florida
Dawson, C. E., Mississippi
Day, Albert M., Oregon
Degroat, Major Russ, Washington, D. C.
Dequine, John, Florida
Dickson, Fred, Georgia
Domogalla, Bernard, Wisconsin
Dragovich, Alexander, Florida
Dupree, Harry K., Alabama
Durham, Leonard, Illinois
Dyckman, Martin, Florida

Easterly, Rudolph P., Louisiana
Eddy, Gerald E., Michigan
Eicher, George, Oregon
Ellis, Wade H., Nebraska
Erkkila, Leo F., Michigan
Estes, Don, Florida
Everin, W. J., Montana
Everitt, B. A., Florida

Fickett, Steve, Florida
Fielding, James R., Georgia
Finucane, John, Florida

Fisher, Mrs. Eddie, Florida
Floyd, Jim, Florida
Ford, Ted B., Louisiana
Foster, Glen R., Nebraska
Freede, Hal, Florida
Freeman, Barry O., Mississippi
Friedman, Herbert J., Florida
Frish, Harry M., Florida
Frome, Harry, New Jersey
Frye, Earle, Florida
Fuller, A. C., Georgia
Fuller, Jeff, South Carolina
Funk, John L., Missouri

Gard, Richard, California
Garlick, Lewis, New Mexico
Gasper, Don, West Virginia
Gatlin, John, New Mexico
Gentry, Glenn, Tennessee
Gibson, Ted, Florida
Godwin, Roscoe, Florida
Gordon, Seth, California
Gottschalk, John, Massachusetts
Grantham, Billy T., Mississippi
Grassl, E. F., New York
Gray, Warren B., Florida
Greeley, John R., New York
Green, Don, Nebraska
Grenoble, John, Pennsylvania
Gresh, Walter A., Georgia
Griffin, Pat, Colorado
Griffith, George A., Michigan
Grover, Ernie, Florida
Groves, Frank W., Nevada
Guerra, Rudy, Florida
Guess, R. G., Florida
Gunter, Gordon, Mississippi
Gutermuth, C. R., Washington, D. C.

Hagen, William, Washington, D. C.
Hall, Gordon E., Florida
Hammett, A. R., Jr., Missouri
Hanson, Willis D., Missouri
Harding, E. R., Florida
Harlan, James R., Washington D. C.
Harlow, Richard F., Florida
Harrell, Tabb, Texas
Harrison, Johanne, Florida
Harth, William J., Illinois
Hassler, William W., North Carolina
Hayford, Robert A., New Jersey
Hazzard, Albert S., Pennsylvania
Heard, William R., Alabama
Heinen, E. T., Florida
Hellier, Thomas, Jr., Texas
Hendershott, Robert, Florida
Henderson, Croswell, Ohio
Henrikson, Carl, New York
Herke, William H., Florida
Herndon, William H., Florida
Hester, Philip G., North Carolina
Heter, Scot, Washington, D. C.
Hicks, Ken, Missouri
Hile, Ralph, Michigan
Hoefelman, Allen, Missouri
Holloway, Ancil D., Minnesota
Holmes, Ray J., Idaho
Hook, Wayne, Florida
Hooper, A. D., Alabama
Horel, George, Florida
Horton, Donald B., Rhode Island
Hough, Eugene, Florida
Houser, Al, Oklahoma
Hueske, E. E., Virginia
Huffman, A. Elwood, Pennsylvania
Huish, Melvin T., Florida
Hulsey, Andrew, Arkansas
Hunt, Burton P., Florida
Hunter, H. A., Florida
Hussey, John B., Florida

Jackson, Sam, Jr., Oklahoma
Janzen, Daniel H., Washington, D. C.
Jenkins, Robert M., Washington, D. C.
Jiacoletti, S. J., Wyoming
Johnson, B. E. Jake, Florida
Johnson, Haddon, Florida
Johnson, R. E., Washington, D. C.
Jones, Albert C., Florida
Joslin, Verne E., Minnesota

Keating, Barclay J., New Jersey
Keefe, Jim, Missouri
Kelly, John Austin, Jr., Florida
Kennedy, A. S., Massachusetts
Kensinger, Bill, Florida
Kim, Ul-Bae, Korea
Kimball, Thimas L., Colorado
King, A. P., Florida
King, Steve, Arkansas
King, Willis, Washington, D. C.
Kinzer, Thomas J., Mississippi
Klima, Bill, Tennessee
Kruse, Charlie, Florida
Kruse, Paul, Florida
Kutkuhn, James H., Texas

Lane, C. E. Tad, Jr., Georgia
Lane, Warden M., Virginia
Langford, George, Florida
Lanier, J. S., Florida
Lawrence, E. W., Jr., Florida
Lawrence, W. Mason, New York
Laythe, Leo L., Oregon

Leahy, Mrs. D. D., Kansas
Leaverton, Paul, Iowa
Leonard, Justin W., Michigan
Leonard, Ross, Idaho
Leporte, Armand, New Jersey
Lewis, William M., Illinois
Little, Edward G., Florida
Loftin, Horace, Florida
Loftus, Ken, Ontario, Canada
Lopinut, A., Illinois

McBay, Glen, Alabama
McClelland, Richard, Florida
McCombie, A. M., Ontario, Canada
McDaniel, T. H., Florida
McDannold, William E., Missouri
McKim, Mrs. L. L., Iowa
McKinnon, Joel L., Florida
McLain, A. L., Michigan
McLaughlin, Charles, Massachusetts
McLellan, Bill, Florida
McMillian, Rhett, Florida

MacKay, H. H., Ontario, Canada
Madden, K. M., Iowa
Mair, W. Winston, Ontario, Canada
Mann, Bert, Florida
Marston, Red, Florida
Martin, D. J., Jr., Florida
Martin, N. V., Ontario, Canada
Martin, R. G., Virginia
Martina, Joseph, Jr., Florida
Marvich, Ed, Alaska
Massmann, William H., Virginia
May, Billie Z., Florida
Meigs, Robert, Washington
Menzel, R. W., Florida
Metcalf, John, Florida
Moffett, James W., Michigan
Mole, Richard, Florida
Moody, Harold, Florida
Moore, George C., Georgia
Morgan, H. R., North Dakota
Moss, Don, Georgia
Moyle, John B., Minnesota
Mullan, James W., Massachusetts
Myers, V. W., Florida
Myrick, Whit, Florida

Nesmith, Marilyn, Florida
Nichols, Hudson M., Tennessee

Oliver, Marion, Florida

Painter, Richard E., Kansas
Palmer, Glen D., Illinois
Parr, Sam A., Illinois
Patton, Mrs. Clyde P., North Carolina
Paul, Robert M., Washington, D. C.
Paulk, Mrs. David, Florida
Paulk, Sylvia, Florida
Pavick, Pete D., Washington, D. C.
Paynter, E. L., Saskatchewan, Canada
Peters, Harold S., Georgia
Pfitzer, Donald W., Georgia
Phelps, Chester, Virginia
Philbin, J. T., Florida
Phillippy, Clayton, Florida
Phillips, Robert W., Florida
Phipps, Frank, Kentucky
Pickup, John, New York
Powell, Jim, Florida
Prather, E. E., Alabama
Prevost, Gustave, Quebec, Canada
Prewitt, Roy, Arkansas
Price, Robert W., New York
Pruginin, Yoel, Israel

Quinn, I. T., Alabama

Rabanal, Herminio R., Philippines
Reed, Jim, Florida
Reed, Ralph, Florida
Rice, Alice, Florida
Rich, Kenneth E., Mississippi
Richards, Russell F., Florida
Riebold, Mrs. R. J., Florida
Roach, Lee S., Ohio
Rose, Earl T., Iowa
Rounsefell, George, Texas
Ruhr, Gene, Tennessee
Rupert, B. J., Mexico
Russi, John M., Florida
Rutherford, R. M., Washington, D. C.

Saila, Saul B., Rhode Island
Sastry, Akella N., Florida
Schafer, Harry, Louisiana
Schneberger, Edward, Wisconsin
Schneider, P. W., Oregon
Schoumacher, Roger, West Virginia
Schryer, Frank, Kansas
Schultz, C. A., Mississippi
Schwartz, Mrs. Patricia J., Illinois
Scott, J. W., Florida
Scruggs, George, Georgia
Seaman, Don E., Florida
Seaman, Wayne R., Colorado
Seaman, E. A., Virginia
Seeland, H. F., New York
Shanks, Charles, Missouri
Shannon, W. T., California
Shell, Wayne, Alabama
Shoemaker, C. D., Washington, D. C.
Shoemaker, Jack, Florida

Simmons, J. W., Florida
Simpson, James C., Idaho
Smith, Lloyd L., Jr., Minnesota
Smith, Marvin A., Georgia
Smith, Spencer H., Georgia
Smith, Stanford H., Michigan
Sneed, Kermit E., Alabama
Snow, Jack, Alabama
Southwell, Don, Florida
Speaker, E. B., Iowa
Sprecher, G. E., Wisconsin
St. Amant, Lyle S., Louisiana
Stanberry, Fred W., Tennessee
Standefer, Mrs. Mutt, Oklahoma
Ste. Claire, Denver, Florida
Steen, M. G., Nebraska
Sturges, Fred, Illinois
Sullivan, John, Pennsylvania
Surber, Eugene, Georgia
Sutter, George, Florida
Suttkus, Royal D., Louisiana
Swartz, Albert H., Massachusetts
Swift, Lloyd W., Washington, D. C.
Swingle, H. S., Alabama

Tabb, Durbin C., Florida
Tanner, Howard A., Colorado
Tarzwell, Clarence, Ohio
Taylor, Lytton, Minnesota
Thomas, V. C., Florida
Thompson, Douglas, Jr., Florida
Thompson, Fred A., New Mexico
Thompson, James G., Florida
Thompson, Seton H., Florida
Timmons, Ed, Florida
Toole, Marion, Texas
Totman, C. O., Washington, D. C.
Towell, William E., Missouri
Towery, Bobby A., Mississippi
Tunison, A. V., Washington, D. C.
Turner, William, Kentucky
Tyson, Edwin L., Florida

Underhill, A. H., New Jersey

Yerger, Ralph W., Florida

Viosca, Percy, Louisiana
Voigt, William, Jr., Pennsylvania
Von Limbach, Bruno, Maryland

Wallis, O. L., Washington, D. C.
Ward, Warren E., Florida
Wayman, Tom, Florida
Webb, Bob, Georgia
Weber, Rene, Wisconsin
Westerman, Fred A., Michigan
White, James M., Florida
Whiteleather, R. T., Florida
Whitney, Richard, Maryland
Williams, Ed K., Georgia
Williamson, Jack L., Mississippi
Wilson, A. L., Florida
Winston, Frank, Florida
Woods, John W., Florida
Wright, Asa T., Michigan
Wright, Thomas J., Rhode Island

Zein-Eldin, Zoula P., Texas

IN MEMORIAM

Ward T. Bower, St. Petersburg, Florida (honorary member)

Arthur W. Henn, Winter Park, Florida

John L. Mackenzie, Montreal, Quebec

N. B. Scofield, Palo Alto, California